MODERN RAILWAY SIGNALLING

BLACKIE & SON LIMITED
50 Old Bailey, LONDON
17 Stanhope Street, GLASGOW

BLACKIE & SON (INDIA) LIMITED
Warwick House, Fort Street, BOMBAY

BLACKIE & SON (CANADA) LIMITED
1118 Bay Street, TORONTO

MODERN RAILWAY SIGNALLING

BY

M. G. TWEEDIE
A.M.I.E.E., M.I.R.S.E.

AND

T. S. LASCELLES
M.I.R.S.E.

BLACKIE & SON LIMITED
LONDON AND GLASGOW

First issued 1925
Reprinted 1927

Printed in Great Britain by Blackie & Son, Ltd., Glasgow

PREFACE

The aim of this work is to give a reasonably full account of present-day Railway Signal Engineering practice.

Signal Engineering is at the present moment developing very rapidly.

With the increasing distance of points from the signal box for manually worked facing and trailing points, viz. 350 yd., and any distance for power-operated points of both types, great savings in time and money have been effected, and still greater savings will be possible in the future.

The perfection of the track circuit has made it possible to introduce many additional safeguards and to eliminate the danger to staff and delay caused by complying with Rule 55.

Automatic train control and train stops prevent drivers overrunning signals at " stop ".

The 3- and 4-aspect signalling systems when installed at suitable places prevent traffic delays, and in consequence avoid the waste of tractive power caused by signal stops and re-starts.

The fog-repeater, acting in conjunction with automatic train control and train stops, enables trains to run with greater safety and punctuality in fog or falling snow.

The introduction of the high-efficiency electric lamp, and the improved quality of lenses, reflectors, and coloured glasses, have led to the development of the daylight signal, fed from primary or secondary batteries.

Science is being applied in all directions—to make trains safer, to extend the carrying capacity of existing lines, and to cut down operating expenses. The Signal Engineer of to-day must have the knowledge and the cultivated imagination which will enable him to recognize and seize opportunities of applying scientific methods and results. Applied Mechanics will come to his aid when he is dealing with levers, cranks, friction of rodding and wires, expansion and contraction of metals, lubrication; Optics will be useful when he is engaged upon lenses, coloured glass, illuminants, reflectors, &c.; and he ought to have a thorough acquaintance with the principles of Electricity and Magnetism. It is to the application of these branches of science that the rapid and increasing development of signalling is due.

The young man in a Signal Department who wants to make himself useful to his chief should make every effort to supplement his ordinary workshop

experience by acquiring a thorough knowledge of modern applied science. The art of signalling can, of course, be most readily picked up from signalling plans, and by making locking sketches, locking tables, and dog charts, but signalling nowadays is a good deal more than this. In fact the designing of a signalling scheme demands an acquaintance with the construction and performance of all the latest appliances available.

The signalling profession has a great future before it. While the Railways Act, 1921, has reduced the number of separate Signal Departments in Great Britain, it has made the Signal Departments which remain of very much greater importance. Two of the four great groups have a Signal Engineer for the whole of their systems.

The two great English-speaking countries of the world have their signalling institutions. There is, in England, the Institution of Railway Signal Engineers (incorporated 1912). The object of this Institution is to encourage and promote the development of the art and science of signalling in all its branches. Its membership of more than 600 includes many of the leading members of the signalling profession throughout the world. In America the Signal Section of the American Railway Association is a body whose reports, specifications, and recommendations are greatly valued.

The demand for economy in operation becomes more insistent every day. Widening of lines—the old expedient for coping with increase of traffic—is, or may soon be, impracticable on account of the cost. The opportunity of the Signal Engineer to display his skill and prove his value is here, and the Signal Department will before long be recognized as second in importance to none of the great branches of technical railway service.

For their courtesy in answering inquiries and in supplying information, the authors take this opportunity of thanking Messrs. British Power Railway Signal Company; General Electric Company; Tyer & Co.; The Railway Signal Company; Siemens Bros. & Co.; Sykes Interlocking Company; Western Electric Company; and Westinghouse Brake and Saxby Signal Company.

They are also much indebted to the Great Western Railway Company for the loan of photographs.

CONTENTS

LIST OF PLATES

MODERN RAILWAY SIGNALLING

CHAPTER I

Principles of Signalling: Signal Boxes

Principles of Signalling.—The earliest form of train protection, which was used before telegraphic and telephonic communication came into use, was to divide the line into sections or blocks with a passing loop at each block station. Trains were then dispatched in the same direction after a fixed interval of time, which was determined according to the length of the section. Instructions were given to the guard to proceed to the next passing-station, and, after waiting for the oncoming trains or train in the opposite direction to pass, to proceed to the next station, where he would receive further instructions.

As a rule trains were run according to a time-table, which specified where the opposing trains were to cross or fast trains were to overtake the preceding slow ones. However, it was sometimes necessary, owing to late running of certain trains, to alter the fixed schedule. These alterations frequently led to misunderstandings and disastrous collisions, and, in order to avoid these, the official responsible for the traffic over a district issued permits which gave the driver authority to proceed, and also stated where the train was required to shunt. This system is still in use in America to a large extent, but is not now used in this country.

The principles of modern signalling are to give the driver accurate and consistently clear information regarding the state of the line ahead, to tell him which route he is to take, and to ensure by every means available that a fault, defect, or obstruction of the signalling apparatus will result in the stop or danger signal being given.

In addition, modern signalling assists the signalman by providing him with indicators to show him whether or not important sections of the line are occupied; with locks on his levers to prevent mistakes due to memory;

and makes his work easier physically, thus enabling him to have more opportunity to study his signalling duties.

The rule books and appendices of railway companies include instructions which cover every conceivable contingency which may arise. Some of these, such as Rule 55, can be met by an appliance, the track circuit, and Rule 40 could be met by the 3-aspect signal.

The Ministry of Transport signalling requirements lay down what is generally accepted as the standard practice in railway signalling.

For the details of signalling methods and schemes Chapter V should be consulted.

Signal Boxes.—As the apparatus for sending the signalman's message to the driver is centralized in the signal box, it is perhaps best to commence by describing the conditions affecting the design and position of signal boxes.

Selection of Sites for Signal Boxes: Construction.—The first consideration is that governing the most suitable position for the signal box. It should be placed as nearly as possible midway between the extreme points which require to be worked, bearing in mind that the Ministry of Transport allows up to 350 yd. in the case of manually worked facing and trailing points and an unlimited distance if power worked. It should also be possible for the signalman to have a clear view of his points and signals whilst standing at the levers which operate them, and at the same time it is an advantage for him to be near enough to the line to be able to communicate verbally with the drivers and guards of trains. Should it be necessary to locate the cabin near any standing works which would obstruct the view, it is often an advantage to have bay windows, such as are to be seen in nearly all signal cabins in America.

Having decided upon the site, it becomes necessary to determine the type of cabin; and this largely depends upon the nature of the ground and the materials at hand. If the ground is virgin soil, a stone or brick cabin is preferable. Some engineers, however, prefer a brick or stone lower part with a wood upper structure from a sill just below floor level. If the ground is loose and unstable, as is often the case in mining districts, a cabin entirely of wood built upon piles is most suitable. One advantage of a wood cabin is that it can be easily moved to a new site without dismantling; but it does not compare with the other types as regards durability or comfort to the signalman. Another type of cabin which can be used when there is not sufficient ground room is one made of wood carried upon an iron bridge across the lines of way; but this is not to be recommended except as a last resource, as there are many difficulties, not the least being that of arranging the lead-out for the rods and wires.

Power signalling not requiring room for pull-wires and rods, a signal box can be mounted on columns in the space between running roads. It should be sufficiently high to be outside the load gauges, which height gives the signalman an excellent view of his yard. The Birmingham north box

at Snow Hill Station, Great Western Railway, is a good example of this type of box (fig. 1).

General Features of Signal-cabin Design.—Fig. 2 shows a cabin which is used on the Brighton section of the Southern Railway. The illustration is so clear that very little explanation is necessary; the following points, however, are worthy of note.

Foundations.—These must be carried down to solid ground, the minimum depth being shown on drawing. The footings and depth of concrete will, of course, depend upon the height of cabin above ground level.

Opening for Connections.—Cast-iron wall boxes may be built in at the

Fig. 1—Birmingham, Snow Hill, North Box, Great Western Railway

front, back, or ends as required, or a very good alternative is to place three or four old rails extending the whole length of the cabin, with cast-iron supports about every 10 ft.

Leading-off Timbers.—Old rails should be built into the brickwork about 13 in. below rail level, and extending from back to front at about 7-ft. centres. They should stand out at least 3 ft. from the front of the cabin, in order that the outside timbers may be bolted down to them. The inside timbers should be 12-in. by 6-in. red fir, clean sawn on all sides, and should cover the floor space between the apparatus timber and the wall on the locking-frame side. The rest of the flooring, which is not required for fixing down cranks, &c., may be of 9-in. by 3-in., laid with about 1 in. space between each; this provides sufficient ventilation to prevent rotting. It is a good plan to use 12-in. by 5-in. timbers for the outside lead-off. This will allow a straight connection from the pedestal cranks to the

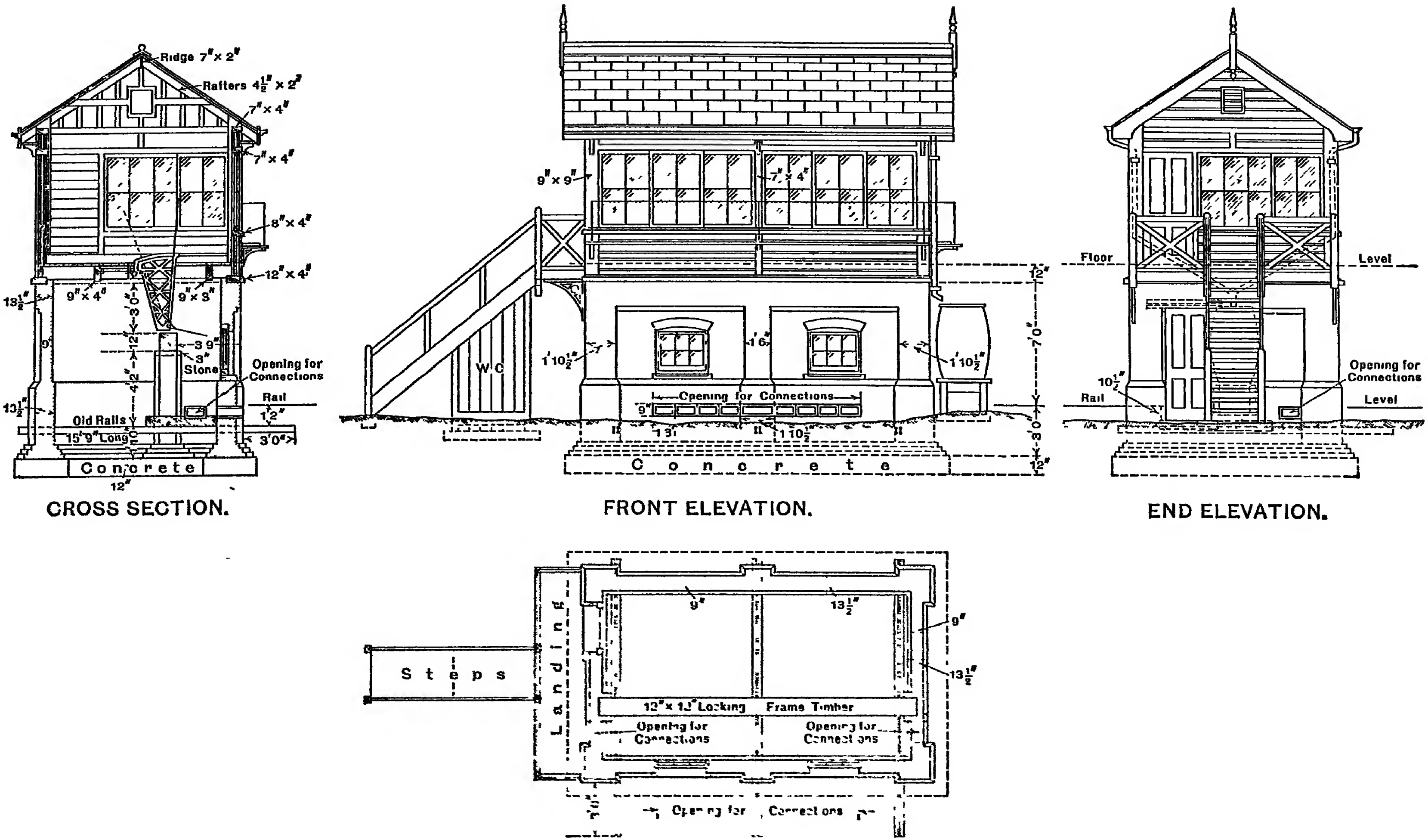


Fig. 2.—Signal Box with Brick Base, Southern Railway (Brighton Section)

Note. If locking frame is fixed in reversed position to that shown on drawing, the upper door to be glazed.

medium high accommodating cranks, and a set-up or set-down connection to the high and low accommodating cranks.

Carriage Timber for Apparatus.—This must be fixed according to the type of locking frame which it has to support, and should preferably extend the whole length of the cabin, resting upon a stone bed at each end, or, in the case of a wooden cabin, securely fixed into a cast-iron pocket attached to the timber uprights of the cabin end. Care must be taken that it is free from twists, especially if the apparatus is one in which each lever is carried in a separate shoe, otherwise the levers will not be in line. 12-in. by 6-in. timber supports are required, about 10 ft. apart, to prevent any sagging.

Floor Trimming.—An opening in the floor must be made for the apparatus; this will require a timber framing into which the floor joists are to be fixed. It will also form an additional support by taking up the thrust of the apparatus.

Flooring.—The floor boards should be either tongued and grooved or ploughed and battened on the under side, in order to prevent water from running through into the locking boxes. The latter method is to be preferred, as the boards wear much longer before breaking the joints.

Windows.—These should be as large as possible, with the glass in large frames, not subdivided into small panes, otherwise it becomes very difficult for the signalman to see clearly at an angle, owing to the great amount of woodwork. Sliding sashes are also better than lifting ones, and should be provided at each end, and also in the middle in the case of a large cabin.

Outside Fittings.—A nameboard painted, or with cast-iron letters screwed on, or cast complete with name on it, will be required on the outside of the cabin. A stage with handrail must be provided for cleaning the windows, and a water butt or galvanized-iron tank for holding rain-water. Receptacles for coal and ash, and a closet, must also be included.

Furniture.—This will consist of one locker for each signalman, one general-stores locker, a stool, desk, notice board, foot-board, battery cupboard, and stove. The latter will not be required if an open fireplace is built.

CHAPTER II

Lever and Locking Frames

The levers for operating the signals and points are placed together at convenient centres and carried by either a 12-in. by 12-in. timber or a girder running longitudinally through the signal cabin. Some engineers prefer to place the levers so that a signalman stands with his back to the line when working the frame, a position which gives him a clear view of his

work, as there is nothing to obstruct the view. Others again, in fact the majority, place the levers so that the man faces the line when pulling; whilst there are a few who place them across the end of the cabin at right angles to the line.

Positions and Spacing of Levers.—Opinion also differs on the question of centres of levers, these varying from 4 to 6 in. The tendency in the past has been to space them at 5-in. or 6-in. centres; but with the increasing size of lever frames they are now almost universally placed at closer centres, thus effecting a great saving in the length of the cabin, a question of no mean importance where cost and the saving of room have to be considered. Another advantage in favour of the 4-in. spacing is that a new frame may be fixed in place of one at wider centres and containing a smaller number of levers without the necessity of extending the signal box to accommodate it.

Another point upon which present practice differs from the past is in the position of the point and signal levers in the frame. In the past the levers working the up signals were placed at one end, the down signals at the other, and those working points and facing-point locks in the middle. The length of the lever tails also varied according to the movement required for the connection; therefore, if it were required to work a signal with a lever which had been previously used for points, the tail would have to be lengthened in order to give the greater movement required.

Locking frames are now made with all levers alike, and drilled for point and signal connections; this allows the levers to be mixed up, so that they may be placed just where most convenient. For instance, a lever for working a cross-over road would have the signals applying to it in each direction, one on either side, in which positions they are most handy to the signalman, as well as convenient for interlocking purposes.

Types of Catch-handle Locking Frames.—There are many different means of interlocking the levers, but as " tappet " locking is the type most used in up-to-date frames, the remarks will be confined to this type. Interlocking may be divided into two kinds, viz. *preliminary locking* and *direct locking*. In the former the interlocking is effected by means of the catch handle, and in the latter by the movement of the lever itself.

The chief point of merit in locking frames of the catch-handle type is that the locking is much more sensitive than direct locking. The mere intention of moving a lever, as expressed by the signalman's grasp of the catch handle, effects the necessary locking of conflicting levers before he actually pulls the lever itself. Then, again, in the case of direct-lever locking which has been subjected to considerable wear, the levers can sometimes be moved some distance without actuating the locking, and the releasing of other levers effected before the lever has fully completed its travel. This is entirely obviated by means of preliminary locking, for it is absolutely essential that not only should the lever be exactly home, but that the catch must be down before the releasing is completed.

Saxby & Farmer's Frame.—Fig. 3 illustrates Messrs. Saxby & Farmer's Duplex pattern locking frame. The levers are mounted upon a turned shaft at 4- or $4\frac{1}{2}$-in. centres as required. Each lever carries two tappets, one being connected to the lever direct and the other to the lever catch handle. The two tappets work in the same groove in the locking box, one sliding over the other, the locks being thick enough to engage with both tappets.

Evans & O'Donnell's Frame.—Fig. 4 shows the "E. & O'D." locking frame. The locking box in this case is placed at an angle of 60°,

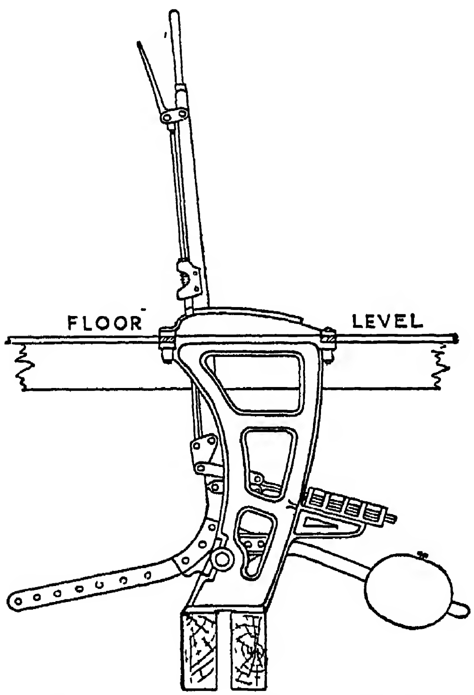


Fig. 3.—Saxby & Farmer's Duplex Pattern Locking Frame

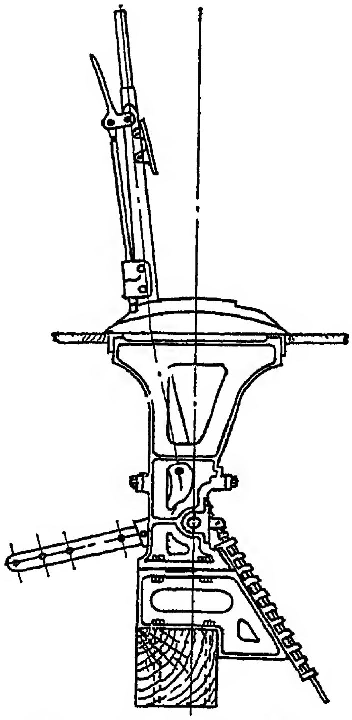


Fig. 4.—Evans & O'Donnell's Locking Frame

which makes it easier for inspection. The tappets are connected to the catch only, and are actuated through the medium of rockers working on the lever shaft. A detail of special or conditional locking is shown in fig. 5.

Dutton's Frame.—Messrs. M'Kenzie & Holland manufactured the frame illustrated in fig. 6. This was designed by Dutton & Co., and is a distinct departure from the usual practice, in that the lever centre comes as nearly as possible directly under the signalman's foot when he is in the act of pulling. This gives him a greater amount of purchase than is obtained by most frames in use. The locks are attached to the bars by means of screws, and it is therefore an easy matter to remove a lock without taking the whole bar out. Some engineers object to the use of screws on the score that they are liable to work loose. If, however, the taper tap only is used, the screws will have to be driven home under effort owing to the

bare thread, and the locks will then hold as well as if they were riveted.

Types of Direct Lever-locking Frames.—The foregoing are the

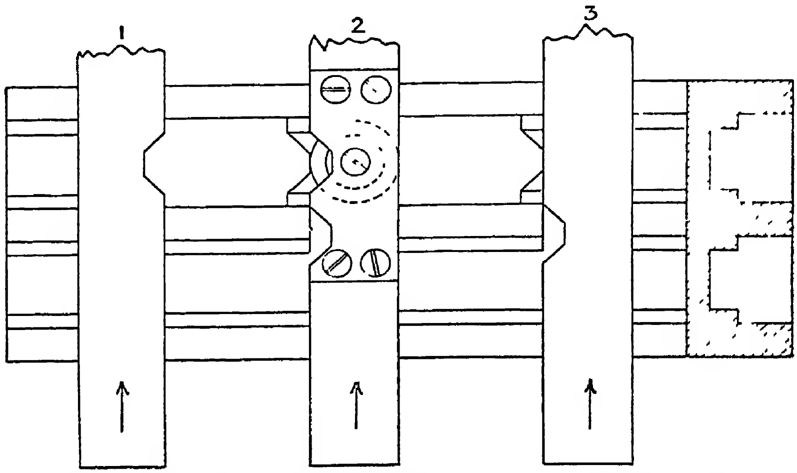


Fig 5—Detail of Special or Conditional Locking on " E. & O'D " Frame

only frames used to any extent in which the locking is actuated by means of the catch handle. We may now turn our attention to direct lever-locking, which may be divided into two classes, viz. that in which the tappet receives the full movement of the lever, and that in which it only receives a small movement at the commencement and finish of the stroke of the lever through the medium of an escapement gear. At this point it would be as well, perhaps, to explain the object of keeping the movement of the tappet as low as possible.

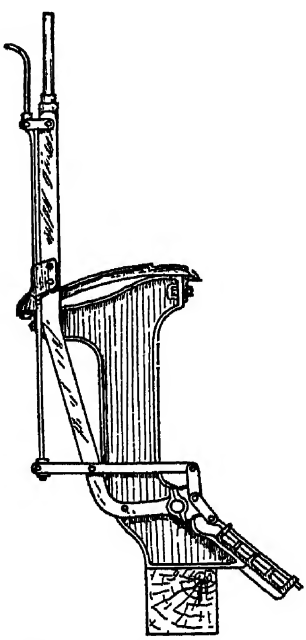


Fig. 6.—Dutton's Locking Frame

Suppose it should be required to place two locks in adjacent channels against the same tappet, so that each should be released when the tappet was in the " over " position, it will be seen that if the stroke of the tappet is greater than the centres of the troughs, there is a possibility of lock A entering the notch B′, which was intended for B; reference to fig. 7 will make this clear. This difficulty is sometimes overcome by making the nose of the lock A larger than B, and cutting the notches A′ and B′ to suit (see fig. 8). Another method is to cut the notch B′ only half-way through the tappet, making the lock B to correspond. These methods, however, are not to be recommended, as they necessitate so many different-pattern locks being used that confusion follows, and any oversight made by a locking fitter in cutting a notch too large, or omitting to alter existing notches when fitting locking in adjacent channels, may lead to serious consequences.

Another alternative is to fix the tappet near to the lever fulcrum, but the disadvantage of this is that the lock is not nearly so sensitive, and, owing to the purchase obtained by the long lever, the locking is liable to be strained and even forced.

Escapement Gears.—We now come to the means adopted for reducing the travel by means of escapement gears, and before proceeding we may consider the advantages and disadvantages. The chief claim is that the " lock " may be placed immediately under the floor-plates, and therefore at a much greater distance from the fulcrum than would other-

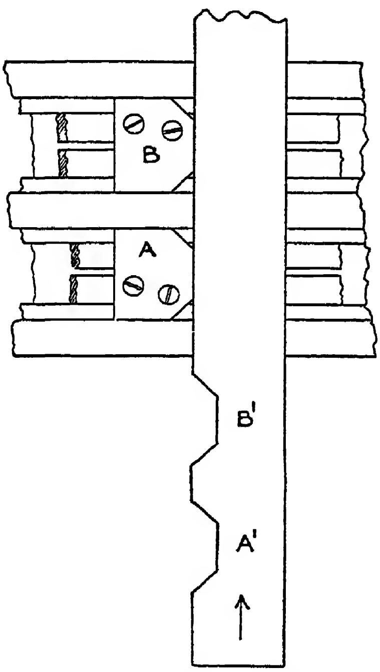


Fig. 7.—Conflicting Notches

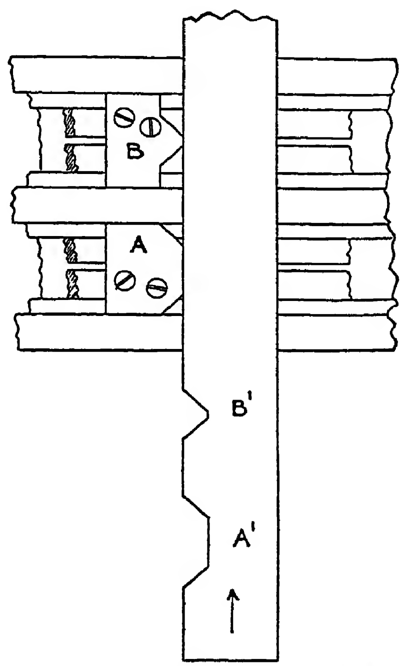


Fig. 8—One Method of overcoming Conflicting Notches

wise be possible, thus obtaining a " dead " lock. Then, again, the locking boxes may be fixed in almost any position—horizontal, vertical, or at an angle. Against this it is urged that the increased number of wearing surfaces and pins tends to make the locking " sloppy " after being in use for some time.

" London Midland and Scottish Railway (North-Western) " Frame.—Fig. 9 illustrates a locking frame used on the old London and North-Western Railway, now the London Midland and Scottish Railway (North-Western Section). It was designed by the late Mr. Webb, and, like most of his inventions, has entirely novel features. It will be noticed that the usual catch handle is dispensed with, and its place is taken by a stirrup placed in the front of the lever, which, upon being pulled down, raises the catch block in the usual way. The locking boxes are fixed vertically, and where a large number of troughs are required they are

divided into two boxes, and the tappets connected with a crossbar, so that one lifts as the other drops, thus equalizing the weight.

Railway Signal Company's Frame.—Fig. 10 illustrates the Railway Signal Company's pattern. The tappets are attached to the levers direct, the locking boxes being arranged in tiers, so that any one tappet may be removed without disconnecting the whole of the locking on the lever.

"London, Brighton and South Coast" Frame.—The late London, Brighton and South Coast Railway's—now the Southern Railway (Brighton Section)—standard frame was adapted from the Stevens pattern. Drop boxes, which slide on the lever, take the place of the usual spring-catch rods. The

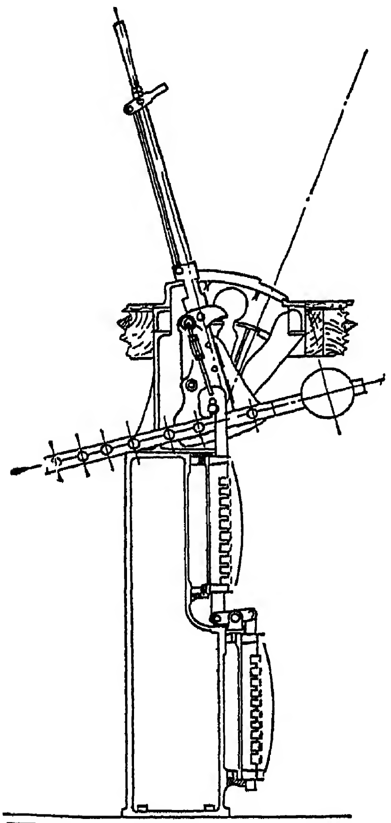


Fig. 9.—Locking Frame, London Midland and Scottish Railway (L. & N.-W. Section)

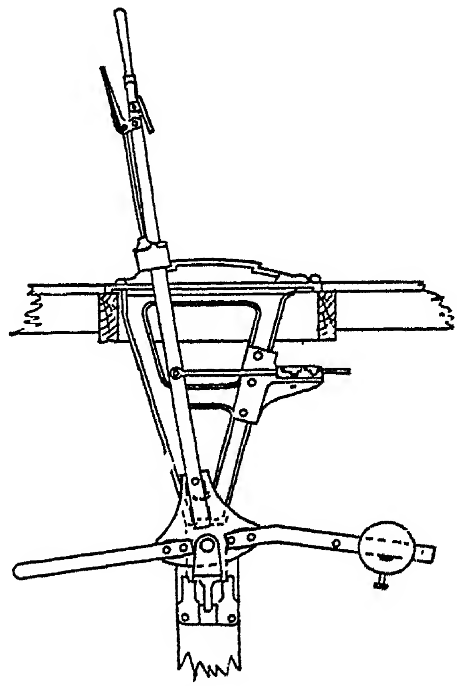


Fig. 10.—Railway Signal Company's Locking Frame

levers are all centred on separate pins, which makes it an easy matter to renew any which are worn.

M'Kenzie & Holland Frame.—In the late M'Kenzie & Holland's early pattern frame the tappets are actuated by means of a cam, which is carried on a turned shaft and operated at the commencement and finish of the lever's stroke by means of a stud fixed to the lever close under the floor-plates. The locking is placed horizontally in one large box, provision being made for five bars in each channel—two underneath the tappet and three on top. A later frame of a novel type has been recently designed by them, and is shown in fig. 11. It will be noticed that there are two tappets attached to each lever, and it therefore follows that the notches in both

tappets coincide only when the lever is in its normal or reversed positions.

W. R. Sykes Frame.—Fig. 12 shows the W. R. Sykes Interlocking Signal Company's method as applied to a "London Brighton and South Coast Railway" frame. The gear consists of a fixed rack and a movable rack running side by side, the latter being connected to the tappet. A pinion which engages with both racks is carried on a pin attached to a box which slides on the lever to accommodate the radius of its movement. Two stops are placed in such positions that they engage with the teeth of the pinion in the two extreme positions of the lever, and consequently prevent the pinion from turning, the rack being therefore drawn with the lever. The movement given is 1 in. at commencement and 1 in. at the finish of the lever's stroke. It should be mentioned that the teeth of the fixed rack are removed at each end to allow the wheel to slide.

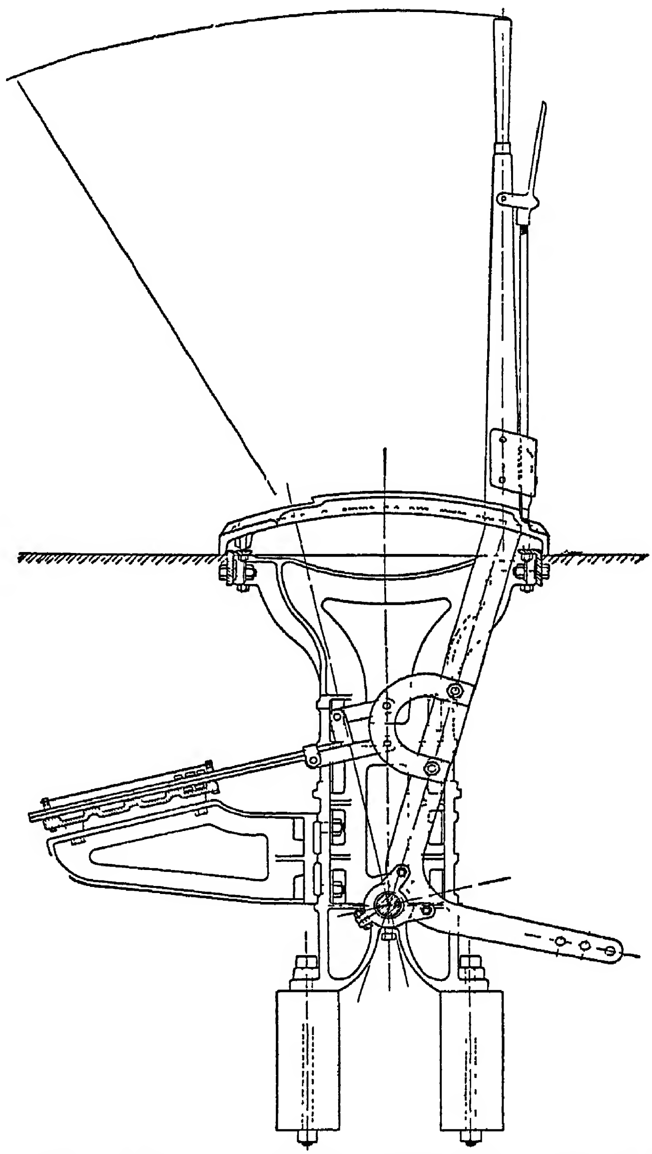


Fig 11 —M'Kenzie & Holland's Duplex Tappet Locking Frame

Sykes & Hallam Frame.—The Sykes & Hallam patent frame, which is shown by fig. 13, has a flat bar with two projections fixed to the lever in such a manner that the projections engage with two pins fixed into a disc, the rotation of the disc imparting a downward movement to the tappet. Here again we have the locking placed at an angle. Arrangements are also made for adjusting the signal wires by means of a screw adjuster fixed in the floor-plates between the levers, a removable handle being used for this purpose.

Ground Frames.—At sidings which are too far away from a cabin to

be worked by it, a small ground frame is used, and either controlled by means of a rod connection or an Annett key, according to the distance. Two very good types of ground frames are illustrated by figs. 14 and 15.

Whilst on the subject of ground frames we may consider the method of controlling them by means of an Annett key. Fig. 16 shows the lock, which is mounted either on the lever or at the end of the frame and interlocked with the lever, as shown. One key only is supplied, and it is arranged so that all conflicting signals must be placed at "danger"

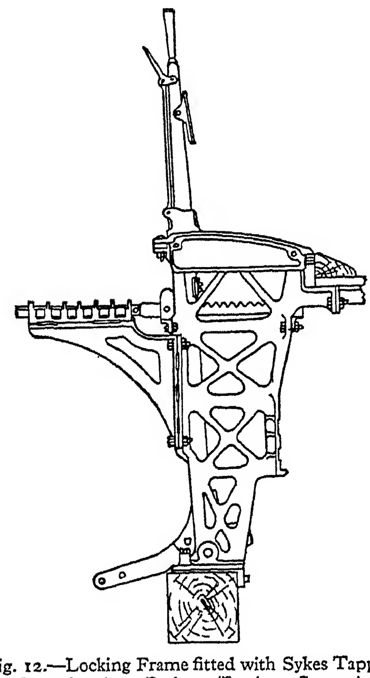


Fig. 12.—Locking Frame fitted with Sykes Tappet Gear, Southern Railway (Br ghton Section)

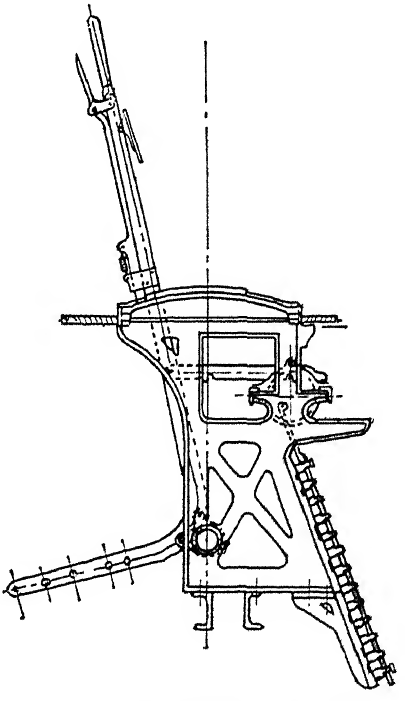


Fig. 13.—Sykes & Hallam Locking Frame

before the key may be turned in the lock. It is now carried to the ground frame and placed in the lock there, and when turned it frees the levers controlling the siding connection. Of course it follows that the key cannot be taken out of the lock until the levers have been restored to their normal position and the key turned in order to lock them again in that position.

Ground frames may be also controlled electrically from the cabin, as described in Chapter XV.

Gate Crabs.—Gates are too heavy to be operated by means of a hand lever, although in the case of small gates it may be done; but a winch is to be recommended for this purpose. Such winches are preferably fixed at the end of the locking frame nearest the level crossing, so that the signalman can see that the roadway is clear whilst closing the gates.

Slot Indicators.—In cases where one cabin slots signals controlled by another cabin an indicator should be fixed in the cabin, behind the lever to which it refers. In some cases the arrangement is a mechanical one, such as a disc or a slide appearing through an opening, but electrical indicators are now mostly used, the advantage of these being that they do not entail additional weight to the signal.

Gongs.—It is sometimes necessary to provide an audible means of signalling be-

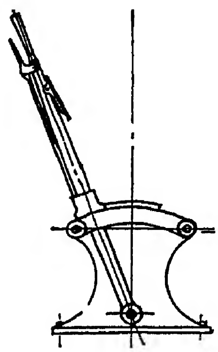


Fig 14.—Ground Frame without Interlocking

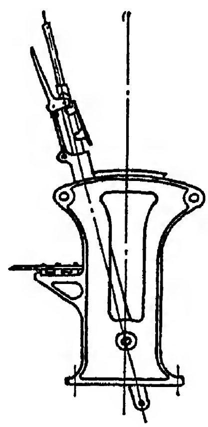


Fig. 15.—Ground Frame suitable for Interlocked Lever

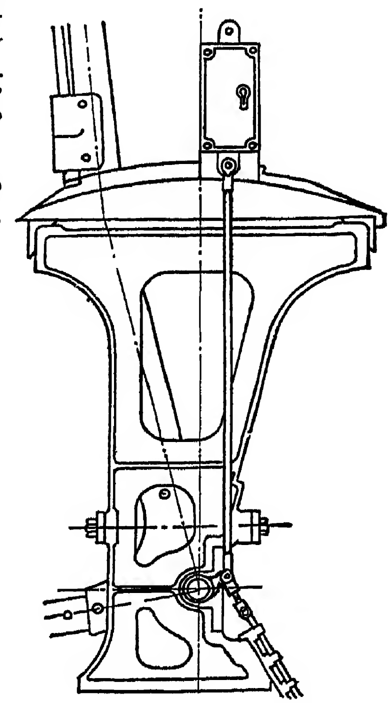


Fig. 16.—Annett's Lock attached to Locking Frame

tween a ground frame and the cabin controlling it, other than by telephones, so that the shunter may ask for permission to use the siding connection and give notice when he has finished his work by means of an arranged code upon a gong. The gong is usually worked by means of a wire connected with one of the levers in the ground frame.

CHAPTER III

Signals

DAY SIGNALS

The two day signals which are most frequently seen are the distant or "caution" signal (fig. 17) and home or "stop" signal (fig. 18). The distinction between the two is that the former has a fish-tailed end to the arm, whilst the latter is square-ended. The meaning of these signals when in a horizontal position is broadly the same on all railways, viz. distant signal, "proceed with caution"; and home signal, "stop". Other running

signals are called " inner " and " outer homes ", " starters ", and " advanced starters ", according to their location, but the meaning is in all cases the same as for the home signal. The utmost importance is attached to the train stopping before it passes a stop signal in a horizontal position, and very serious notice is taken of any infringement of this rule. When these are at an angle downwards to the post, " proceed " as indicated.

Semaphore Arms.—The arms, which vary on nearly every railway, are fixed on a spindle running through the post, or, better still, are carried in a bearing fixed on the side of the post, as on the Southern Railway (Brighton Section), and London Midland and Scottish Railway (North-Western Section). They are usually made of cedar or mahogany, and vary in length from 4 to 5 ft., being about 10 in. wide at the end, and tapering slightly in width and thickness towards the fulcrum. On the London Midland and Scottish Railway (North-Western Section) corrugated-iron arms are employed, but, except on that line, they are not used to any extent in this country. Enamelled-iron arms are also favoured by some railways owing to the ease with which they can be wiped clean.

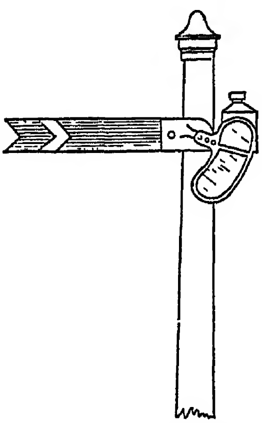


Fig 17.—Distant Signal Arm, Southern Railway (Brighton Section)

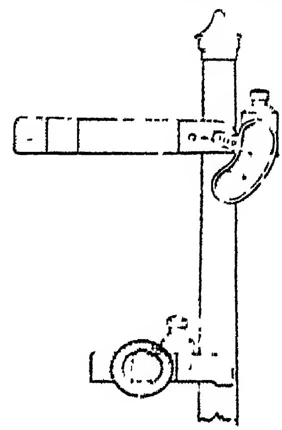


Fig. 18.—Home Signal and " Calling-on " Arm, Southern Railway (Brighton Section)

On some lines the spectacle and arm casting are made in one, notably the Southern Railway (South-Western Section); others provide a means of adjustment to suit the taper of the post, and unless this is done, it follows that if the arm is fixed on the main mast of a bracket signal where it is about 10 in. wide, the lamp would be out of centre with the spectacle.

On the London and North-Eastern Railway (Great Northern Section) and the late Taff Vale Railway, now absorbed by the Great Western Railway and others, a somersault arm is used. The centre being some distance from the post, the arm is then perfectly balanced without aid of the spectacle, which is carried on a separate spindle. A very clear signal is given when the arm swings parallel with the post, and it compares very favourably with other patterns with regard to ease of working.

Low-speed signals, however, differ very greatly on various railways, both in shape and meaning. We have " calling-on " arms, " backing " signals, " shunt " signals, and " siding " signals, illustrations of which are given in figs. 18 to 21.

Home signals are placed at the fouling points of junctions, cross-over roads, siding connections, at the entrance to a station, or at a splitting point of a junction. The distant signal is placed 800 yd. or more in the rear of the home, according to the gradient, curves, &c. It is interlocked

with the home and starting signals, if the latter are provided, so that the clear indication can only be given when all the signals are lowered for proceeding into the next section.

Starting Signals.—Starting signals are located at the end of a platform or in advance of trailing points. In this position they protect the entrance to the next section, and trains may therefore draw up to them during shunting operations. For this reason they should be at least a full train-length in advance of the trailing points, in order that a driver should not have to pass the signal at danger when backing his train into a siding or through a cross-over road. If this cannot be done, advanced starting signals are sometimes fixed to provide the necessary protection. It should always be possible for a signalman to see a train or engine standing at the starting or advanced starting signals; but if, owing to some obstruction,

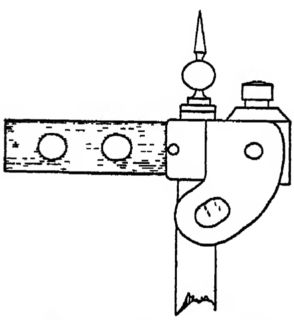


Fig 19 —Backing Signal, Great Western Railway

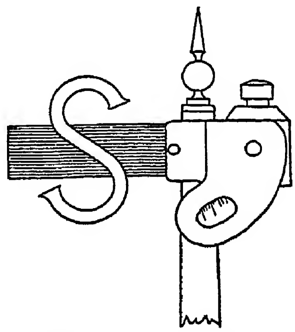


Fig 20.—Shunt Signal, Great Western Railway

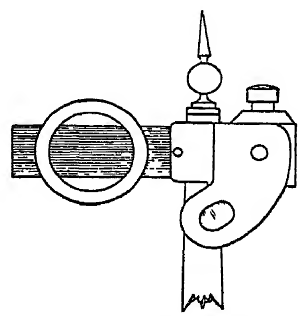
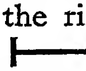


Fig. 21 —Siding Signal, Great Western Railway

he cannot do so, some means of indication, operated either by fouling bars or track circuit, must be provided (see Chapter IX). The same remark, of course, applies to the home signal, but as a rule this signal is placed quite near to the box, and it is only under exceptional circumstances, such as during fog or falling snow, that the view is obscured.

Calling-on Signals.—A calling-on arm is usually placed beneath a home signal when the latter is some distance from the signal cabin; it is used for calling a driver on as far as he can see the road clear, and very often the signalman communicates verbally with the driver, giving him instructions as to how far to proceed. These signals are sometimes arranged to show no light in the danger position at night time, and the calling-on and home arms are interlocked. It is the practice on some lines, however, to give the home and calling-on arms together in order to conform with their rule that a driver shall not pass any stop signal at danger. Different shaped calling-on arms are used by various railway companies. Some adopt the ringed arm, others a diamond, and a few provide this  or this  shape.

Shunting Signals.—With regard to shunting signals, some companies use a short post, about 12 ft. high, with a miniature arm sometimes carrying the letter S; others, again, use a disc, which is fixed on a post

if the view is likely to be obscured by vehicles standing on an adjacent line. If the view is perfectly clear, a ground signal suffices. In any case the lights should be small, in order to distinguish them from the running signals.

Ground Signals.—The ground signals, when fixed near to a running road, exhibit a small white light at night. If a red light were shown, it would be very disconcerting to a driver, and might very well be taken for a hand lamp.

In the past it was the custom to attach this ground signal to the tongue of the points. By this means it simply showed the position of the points,

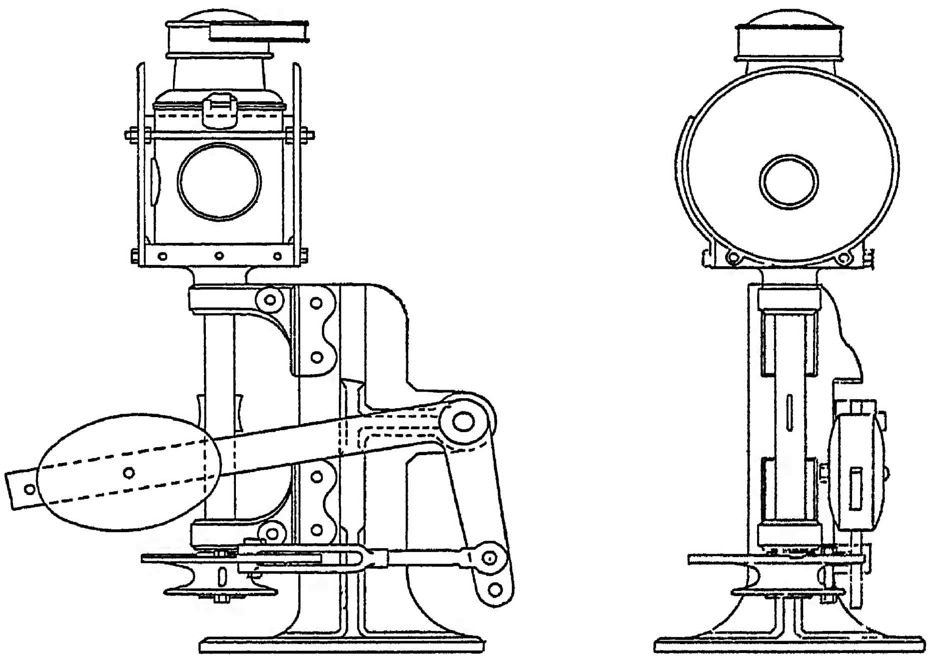


Fig. 22.—Independent Ground Disc, London and North-Eastern Railway (G. N. Section)

and as such it was called a " point-indicator ". The disadvantage was, that if two indicators were fixed, say, one on each end of a cross-over road, both were rotated at the same time, and therefore gave signals in conflicting directions.

A ground signal, which is used to a considerable extent, consists of a square base carrying round targets, which are painted red and green. The base also carries the lamp, and is rotated one quarter of a revolution, thereby presenting the red or the green target, as the case may be, to the driver. Holes are cut in the targets for the lamp to show through (see fig. 22). In some patterns the lamp remains stationary whilst the targets revolve, in which case they must carry red and green lenses. The " Great Eastern Railway " pattern has the targets attached to the lamp itself (see fig. 23).

Another type, as used on the Southern Railway (South-Eastern Section),

has an arm fixed in the horizontal position on one side of the lamp case and in a downward position on the other—the effect, when rotated, being that of an arm lowered from the danger to the clear position.

Fig. 24 shows the pattern used on the Great Western Railway; this is a miniature arm or dwarf signal. One feature is that it is a ground signal and detector combined. The "London and South-Western Railway" type is somewhat similar, the arm being made of india-rubber at the end. Another pattern used by this company is shown in fig. 25; the target in this case is lowered nearly to the horizontal position when at "clear".

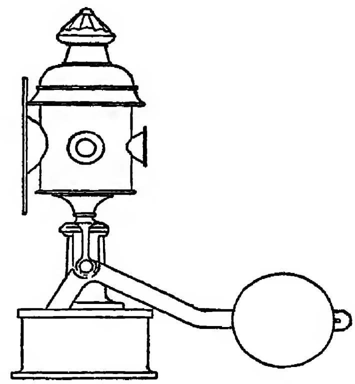


Fig 23.—Ground Disc, London and North-Eastern Railway

Almost any of the foregoing types may be worked direct off the points by means of a rigid connection, if they are required as point indicators.

Signal Posts.—The signal posts used in this country are largely of pitch-pine, although iron is used on some railways, notably the Southern Railway (South-Western Section), and the Scottish lines, fig. 26. The posts should be 7 in. square at the top, and taper $\frac{1}{8}$ in. in the foot in

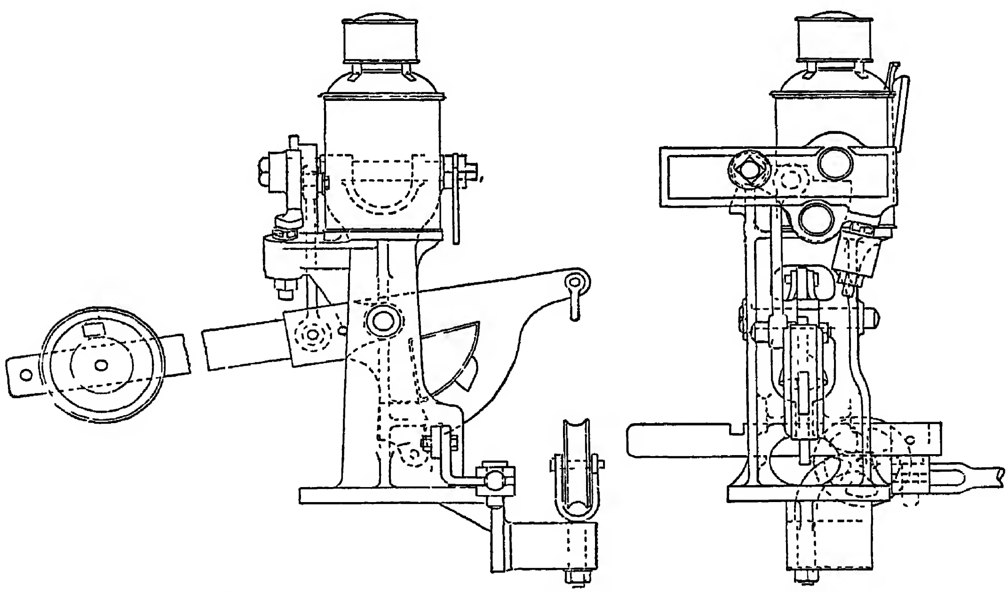


Fig. 24.—Independent Ground Signal, Great Western Railway

each direction; 5 ft. in the ground is sufficient for all posts up to 20 ft., and each additional 10 ft. of height should have 1 ft. more butt in the ground. The butt should rest on a crossing made of 6 ft. of 12-in. by 6-in., with 9-in. by 3-in. spurs on each side; or another method is to fix land ties about 18 in. below ground level. All timber below the ground

line must be treated with some preservative, such as coal-tar or creosote, and above ground it is wrought and painted, usually black or chocolate, up to 6 ft. from the ground, and either white or stone-colour above that height.

The dolls may be supported by cast- or wrought-iron brackets, or by wood stringers. Cast-iron brackets themselves are hardly suitable as they are liable to break under severe twisting strain due to wind pressure. A very good method is to let the stringers into the main posts and dolls, the whole being braced together by bolts and supported by a cast-iron bracket. This method is used on the Southern Railway (Brighton Section).

On the London and North-Eastern Railway (Great Northern Section),

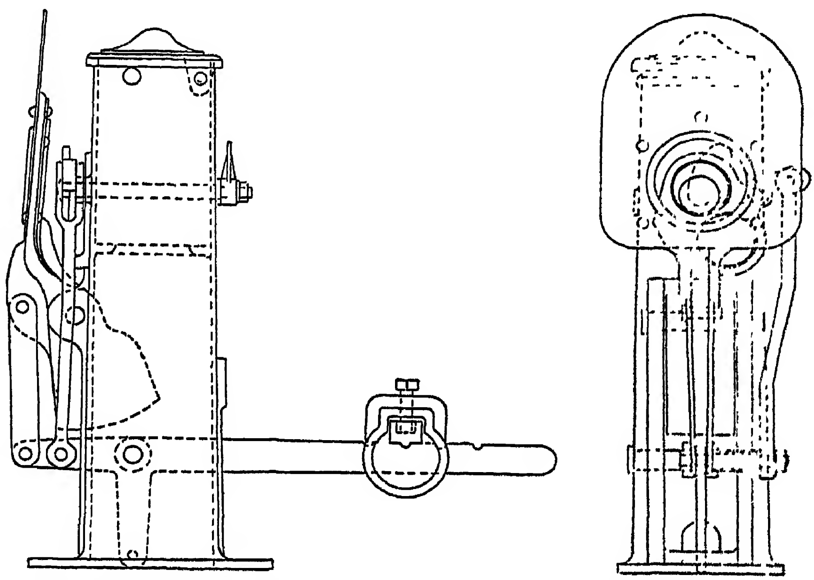


Fig. 25.—Independent Ground Disc, Southern Railway (L. & S.-W. Section)

the doll is fixed into a pocket formed in a wrought-iron lattice bracket, stringers being therefore unnecessary.

Of recent years ferro-concrete posts (fig. 27) have been introduced, the shortage of wood during the years of the War causing this form of construction to be adopted. It is claimed that posts made in this way are cheaper than those of wood, and cost next to nothing to maintain as no painting is required, and their life should be very long indeed. Posts of concrete have to be made with the necessary bolt holes for the fittings in the correct position, and carefully designed templates are required in consequence. It is not generally possible to drill further holes in these posts after they are cast. If an extra attachment has to be made, it is necessary to clip it to an existing fitting or clamp it round the post. These posts are heavy and brittle, and need more labour to erect than the same size of wood post.

Wrought-iron lattice posts, which are adopted on the Southern Railway (South-Western Section), and some of the railways in Scotland and

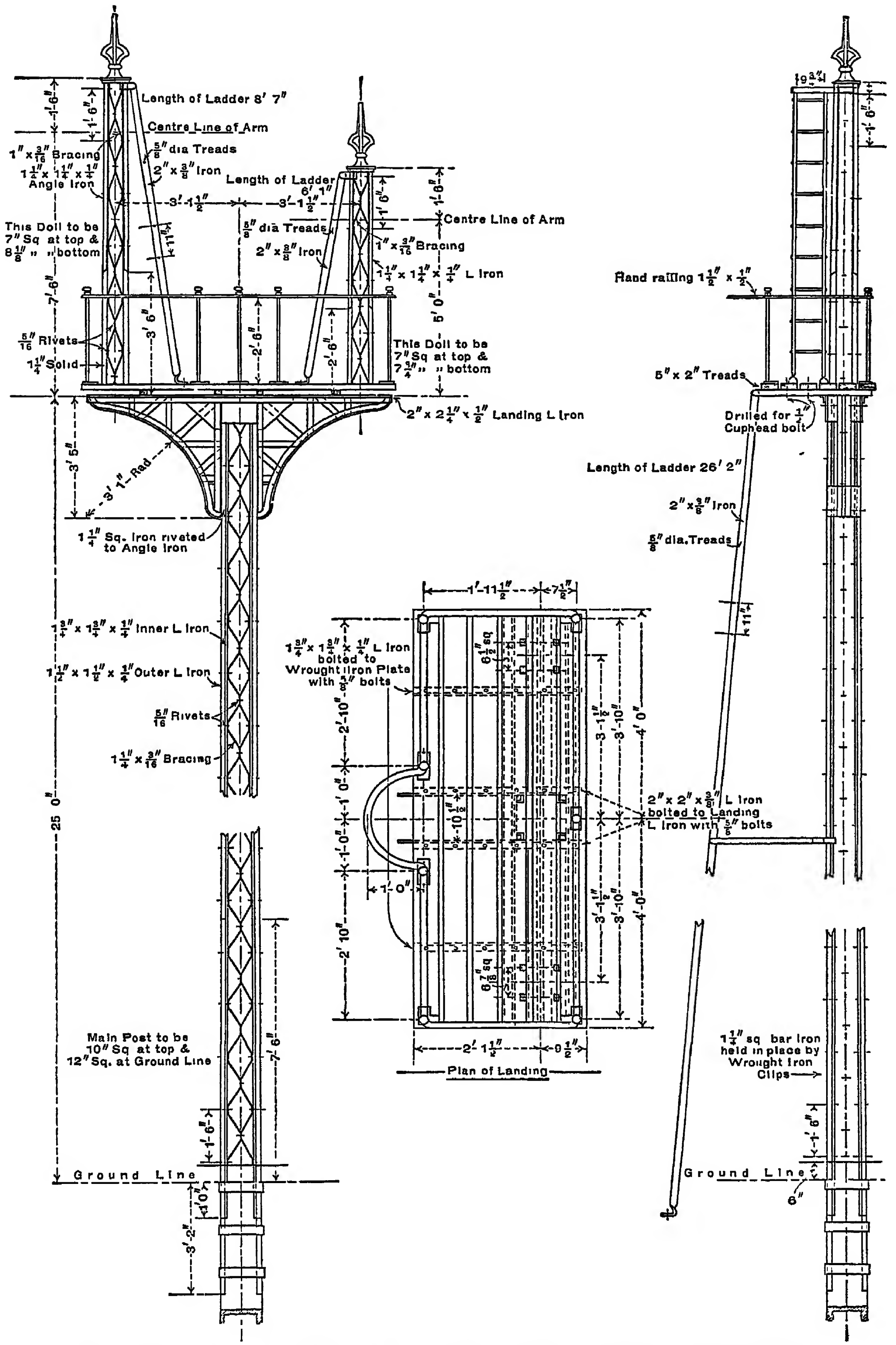


Fig. 26.—Light Type Double-bracket Signal Post, Southern Railway (L & S. W. Section)

elsewhere, are shown in fig. 26. The short, straight posts are fixed to cast-iron bases by means of wrought-iron bands. The larger posts are plated from just above the ground line to the bottom, and are attached to four cast-iron bases, one on each side, so as to form one large base.

Some engineers prefer to place the lever plates on the main post and operate the arms from them by means of rocking shafts and down rods; others, again, carry the wire connections to the dolls, and place the lever plates on the dolls just below the arm. It is also an open question whether wire cranks or swivel wheels are best for negotiating bends. Some means of adjustment must be provided in the down rods, either by adjusting screws or adjusting joints, and long rods must have guides fixed about every 6 ft.

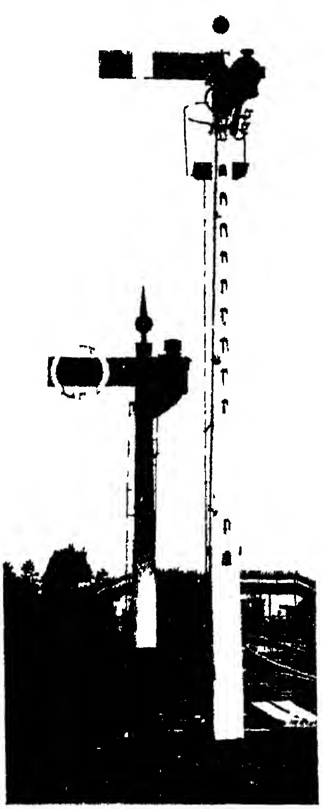


Fig. 27.—Ferro-concrete Signal Post, Great Western Railway

Galleries and Ladders.– In the case of bracket signals a gallery must be provided for the men to reach the dolls. It should be about 3 ft 6 in. wide, and may be fixed half on each side of the dolls or else entirely at the back; the latter method is preferable, as it gives more room. Longitudinal or transverse treads may be used for the flooring – they should have about 1 in. gap between each. The handrail will require to be about 2 ft. 6 in. from the gallery, with a ring just over the ladder, and supported at frequent intervals by means of wrought-iron supports carried in cast-iron shoes which are held down to the treads by means of coach screws. The Southern Railway (Brighton Section) fix the handrail supports into the landing brackets, which is a stronger method than the former.

A ladder will be required for the main post and one for each doll, the latter terminating in a stage and a ring to protect men whilst cleaning the spectacles, &c. Long ladders should have stays fixed at intervals to prevent sagging. The London and North-Eastern Railway (Great Northern Section) fix cast-iron treads to the post, which take the place of ladders.

Pinnacles and Guy Wires.—A cap or pinnacle made of wood, iron, or zinc, is fixed at the tops of the posts and dolls. It gives the post a finished appearance, and at the same time provides a protection from the weather.

All bracket posts and straight signals over 30 ft. in height should be guyed; for this purpose an eyebolt will be required just under the pinnacle

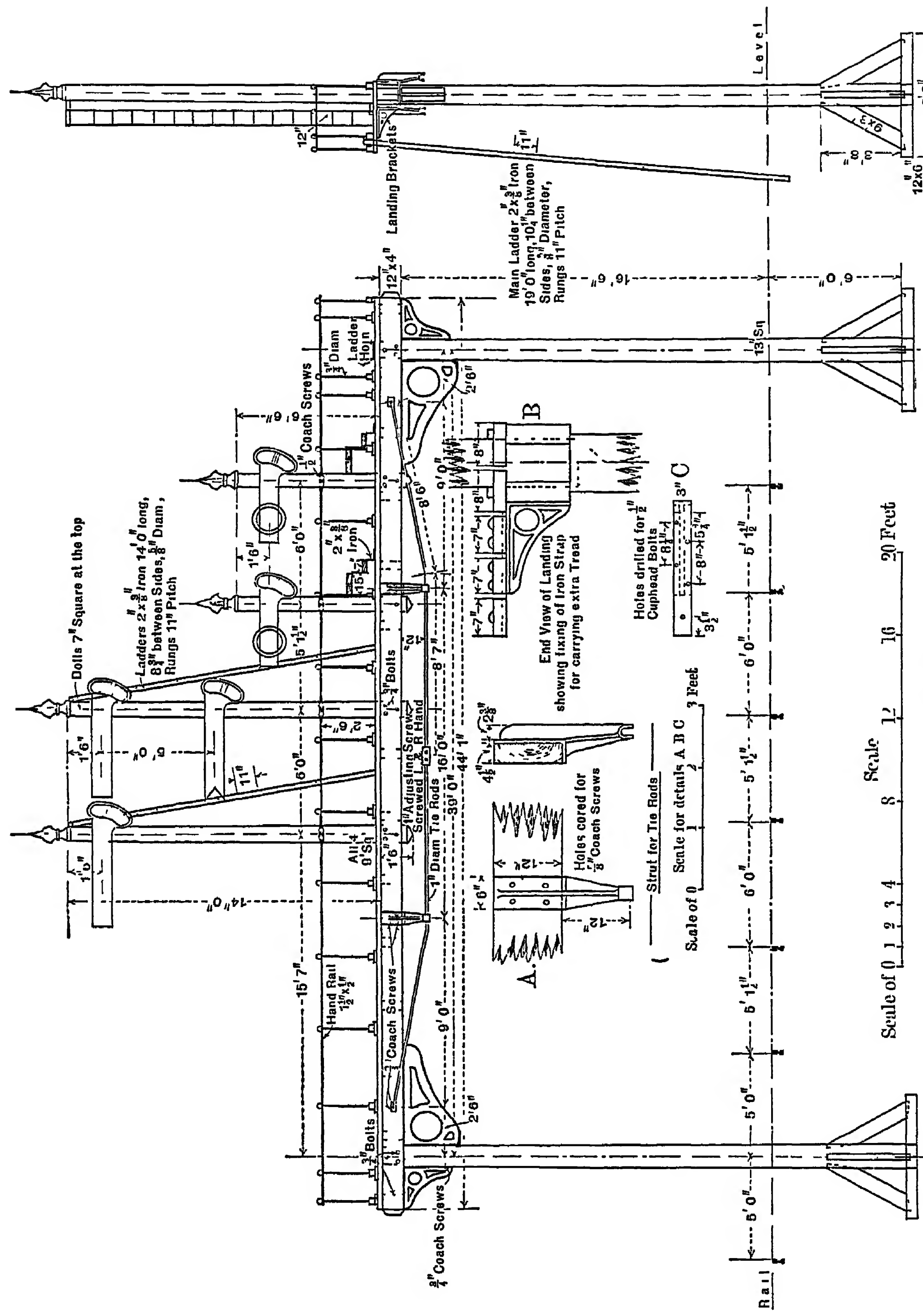


Fig 28 —Wood Bridge Signal

to which the guy wire is attached. In cases where the guys have to be carried over the lines a 20-ft. straining-post must be fixed, from the top of which short guys must be carried to cast-iron anchors buried in solid earth. Some means, such as a ratchet, must also be provided for straining

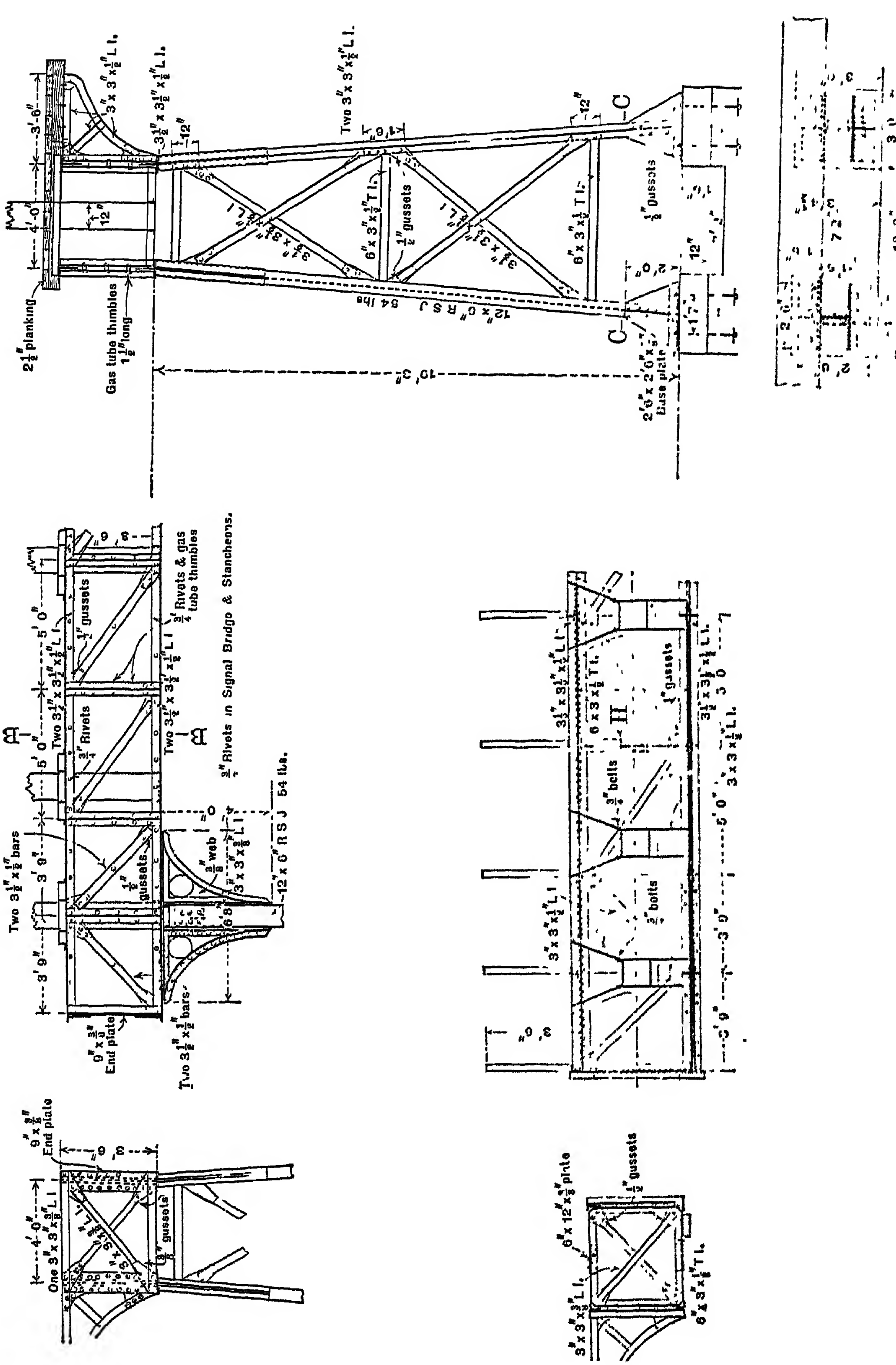


Fig. 29.—Iron Signal Gantry, Southern Railway (Brighton Section)

the wires. The guy wires should be of No. 17 gauge, 7-strand, galvanized-iron wire.

Bridge Signals.—Details are given in fig. 28 of a bridge signal made of wood throughout. Wood stringers are used, into which the dolls are recessed in a similar manner to the bracket signals—the stringers, however, should be rather heavier, owing to the increased span, and truss rods should also be provided to prevent any sag.

Fig. 29 illustrates an iron gantry provided with pockets for carrying the wood dolls. It is used on the Southern Railway (Brighton Section), and was designed by Mr. C. L. Morgan, when chief engineer to the late London, Brighton and South Coast Railway.

NIGHT SIGNALS

The usual night signals employed in Great Britain are a red light for danger or " stop ", and a green light for " proceed ". Back spectacles or blinders should be provided behind the lamp in cases where the signalman cannot see the front of the signal. They should be arranged so that a small white light is exhibited when in the danger position, and that no light is shown when the signal is lowered.

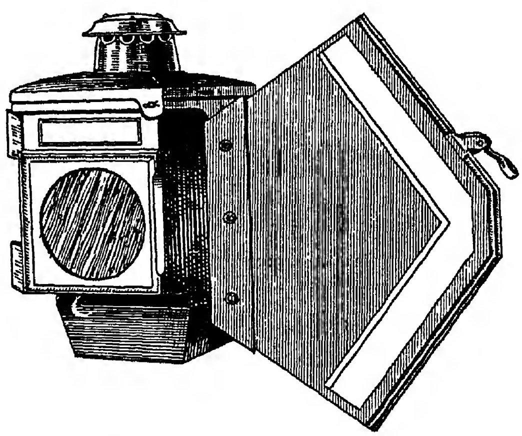


Fig. 30.—Luminous Fish-tail Lamp

At one time a white light was employed for the " proceed " indication, but owing to the danger of a coloured glass breaking or of a light alongside the railway being mistaken for a signal-light its use was discontinued. White lights are still found in some Continental countries, especially in France. For a long time there was no distinction between distant and home signals at night. Theoretically this was very unsatisfactory, but in practice the difficulties arising from such an inconsistent arrangement were less than might have been expected. Nevertheless a distinction is desirable, and in recent years two arrangements have been adopted with this end in view. The first consists of a special lantern (fig. 30) having a reflecting extension arranged to illuminate a white fishtail next to the ordinary coloured light; unless the lantern be kept very clean, however, this fishtail is not visible at any great distance. This method has the advantage of retaining the colours red and green for all purposes. The second arrangement consists in substituting a yellow light for the red in the distant signal, and has found considerable favour in some directions. It is important to secure a very distinctive shade of yellow glass not likely to be confused with red or white. Yellow lights are now extensively used

in the United States and are standard for distant signals in Belgium, Germany, Italy, Denmark, and Norway. When three-position signals are used the 45° indication is usually given by a yellow light, but the New South Wales and Chicago and North-Western Railways exhibit red and green together for this indication. For shunting signals small white lights are now much used to indicate danger, and purple or blue lights may also be seen, but their visibility is very poor. Night signals are very important from the driver's point of view, and it is to be regretted that this subject has not received the scientific treatment which it deserves, signal glasses and lanterns having too often been constructed on rule-of-thumb methods, and their cleaning and adjustment left in inexperienced hands. The result has been that the signal lights are liable to be far from satisfactory Oil lanterns at one time had to be attended to every day, but long-burning lamps have been introduced which will go without attention for several days. To obtain good results with these lamps it is essential to keep them scrupulously clean and carefully trimmed and fixed.

Lamp brackets must be adjustable to make allowance for the varying thickness of the post. As a rule a spigot is provided, which fits into a socket in the lamp case.

Some lamps consist of two parts, an outer case and an interior. The former is best made of copper throughout, with a 6-in. bull's-eye in front and a small 2-in. lens at the back. Both should be adjustable, so that the light may be focused in the right direction to suit curves of the line. The interior may be made of tin, and should be suitable for burning paraffin oil.

Long-burning lamps of the Adlake and Signalite patterns have no separate interior cases.

Acetylene gas has been used to some extent for signal lighting, either as a steady light or as an automatically flashing light, the flashing being used to emphasize a particular class of signal, such as a distant signal. Electric lighting is also used, especially in the United States, and is frequently controlled by track circuit on the approach principle, the lights being normally extinguished and only switched on when a train approaches within a certain distance. This effects a considerable economy where trains run at infrequent intervals. Another arrangement, which may, of course, be combined with the approach control, is what is known as the sun relay, a relay which is sensitive to daylight and adjusted so as to cut the lights completely out of circuit while the light of day does not fall below a given intensity. Electric lighting enables very good lights to be given, unaffected by winds and requiring comparatively little attention. The lamps used should be specially made so as to concentrate the greater part of the light at the focal point of the lens of the lantern. At the same time due regard should be had to the necessity for spreading the light to a certain extent on curves and enabling the driver to get a fairly good light when close up to the signal.

With the demand for a true yellow night indication, it has been necessary for signal engineers to study much more thoroughly than in the past

the question of illuminants and the colour of spectacle glasses and lenses.

When oil, paraffin, is used as the source of light, and long-burning lamps are required in order to save maintenance charges, the light emitted is very small, being in the neighbourhood of 1 c.p. on a horizontal axis.

It is important, therefore, that the lens provided should be of correct shape, the glass must be of good quality, and the distance of the lens from the flame must be adjustable, so that the best effect can be obtained. Until recent years it is unfortunately true that this last condition has not been appreciated, with the result that the signals given at night left a good deal to be desired.

On some railways special inspectors are appointed whose sole duty it is to see that the best possible light is being obtained from the signal lamps.

It is usual to obtain the coloured indication by placing a flat piece of glass of the desired colour in the spectacle[1] attached to the arm, and outside the lens so that the light is projected through it by the lens.

The choice of tint of the glass has been found to be a matter of difficulty, and not such a simple matter as it had been considered until recently.

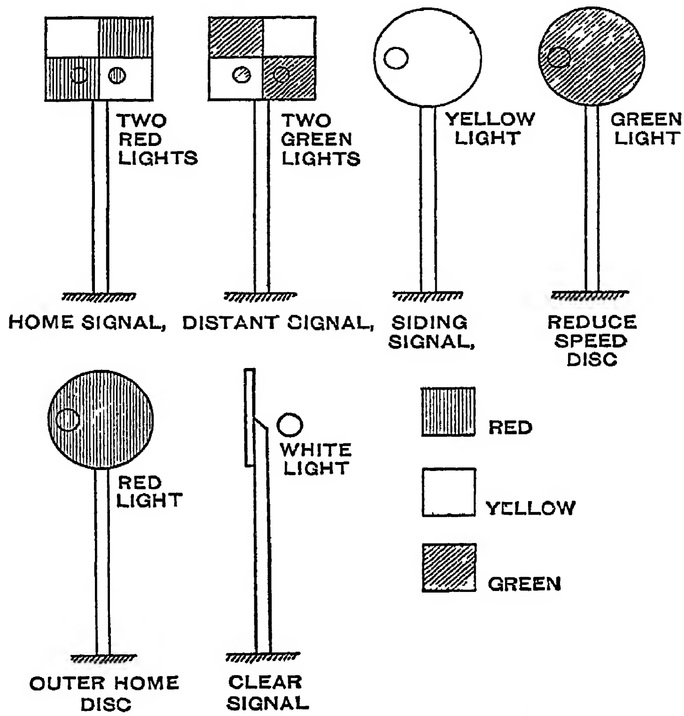


Fig. 31.—Types of French Disc Signals

With different illuminants, paraffin, gas, electricity (carbon filament, metal filament, and gas-filled lamps), different colour values are required, both tint and depth of colour having to be chosen for the respective illuminants.

If an illuminant is rich in red rays, then the tint of the red glass need not be so deep when used with an illuminant not possessing this quality. The deeper the colour tint is the stronger must the illuminant be to obtain the same brightness of the signal.

OTHER FORMS OF SIGNALS

In Great Britain the semaphore signal is now universally employed for main running movements, except where it has been superseded by the

[1] Spectacle glasses with a curved surface are now in use which reduce troubles due to the reflection of strong external lights.

recently introduced light-signals. This is also the case in the United States, but on the Continent other forms of signal are still much used. This is particularly the case in France where disc signals are used for most

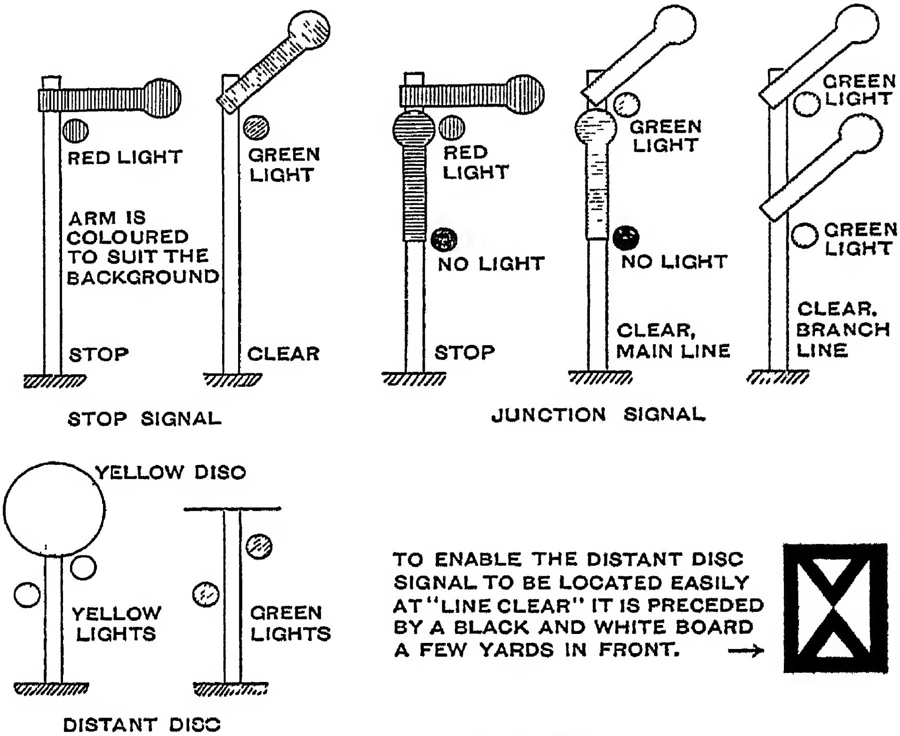


Fig. 32.—Principal German Signals

purposes, although semaphores are employed as well, generally as block-signals not interlocked with the points in any way. In fig. 31 may be seen some of the various types of disc signals used in France. They are practically invisible when at clear, as they rotate on a vertical axis so as to present the edge of the disc to the approaching train. In this position white lights are shown, while in the other position red and green lights, either singly or in combination, are employed according to the meaning of the disc. Disc signals are also to be found in some other countries, but generally only as distant signals, as in Germany. The German signalling code prescribes semaphores for stop signals and discs for cautionary or distant signals, the chief forms being shown in fig. 32. The junction signal is peculiar and is based upon the theory that a red light must never be passed

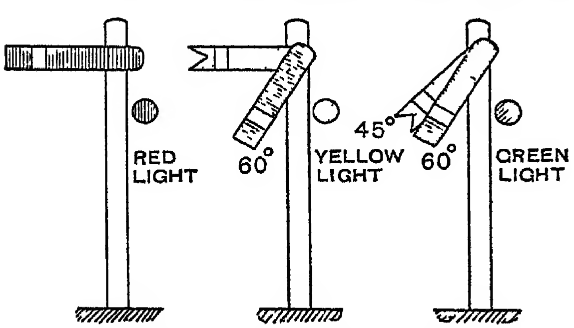


Fig. 33 —Italian State Railways Home and Distant Signals on same Post

during a running movement, and finds favour in those other countries which follow German practice in railway operating, such as Switzerland. In Italy English practice is largely followed, but home and distant signals when on the same post are superposed and not fixed at different levels, as illustrated in fig. 33. The independent ground shunting signals so

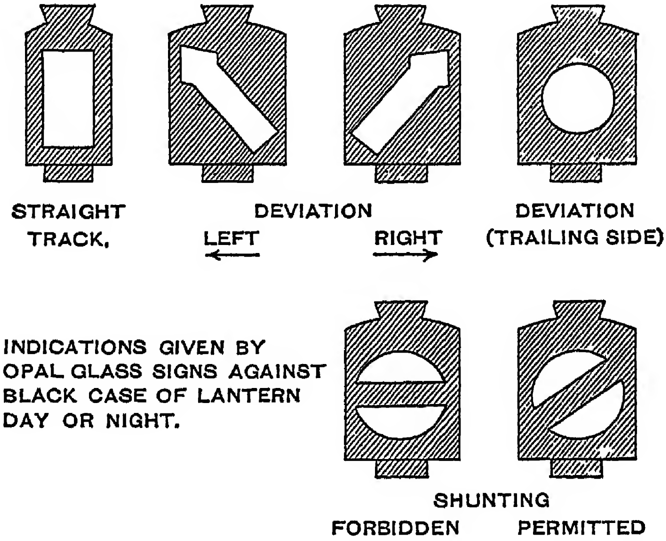


Fig. 34.—German Point Indicators and Shunting Control Signal

frequently used in England are not seen to the same extent abroad, it being the usual practice to have indicators which merely show the position of the points, these being supplemented at certain places by additional signals, called shunting control signals, which may often apply to several tracks. Fig. 34 illustrates some German point indicators and a control signal. This practice gives rise to a great number of indicators, as every pair of

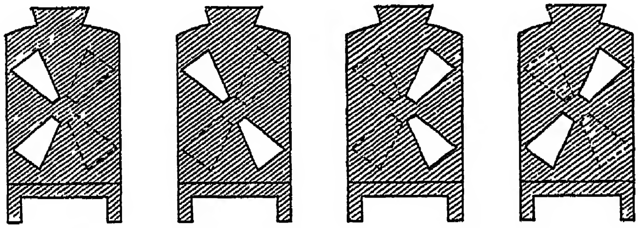


Fig 35.—Double Slip-switch Indicator, Cauer's Patent

points must have one. In the case of single and double slip-switches, however, a special indicator is sometimes used, serving for all the four possible movements for which the points can be set. One such signal is shown in fig. 35, and there are other designs in use or on trial. In Belgium a new code of signals has been introduced since the War, and as it employs three-position signals it is dealt with on p. 53, under that heading.

CHAPTER IV

Ground Connections

In Great Britain all points, facing-point locks, scotch blocks, and movable diamonds in running lines are operated from the cabin by means of rigid connections, whilst the signals are worked with wire connections.

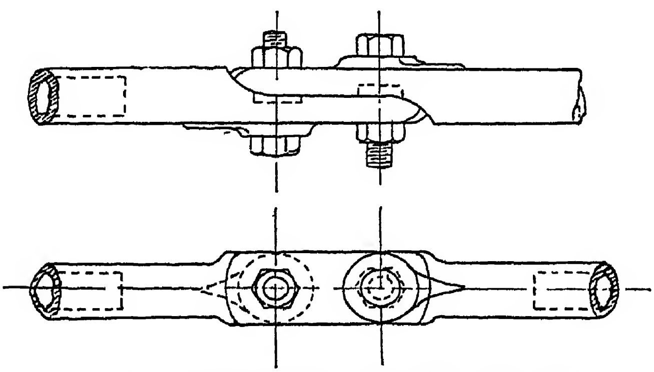


Fig 36.—Point-rod Coupling, Great Western Railway

The rigid connections consist of either 1¼-in. external diameter piping or tee- or channel-iron carried in traversing rollers placed about 2 yd. apart.

Connections for Point-rodding.—Several methods are used for connecting the round rodding, the most usual being to weld a solid plug in the end, and afterwards screw the end. This allows a screwed socket to be used for connecting. Another method is to rivet a plug in one end which fits into the open end of the adjoining rod. A taper key is then driven in and afterwards twisted to prevent it from coming out again.

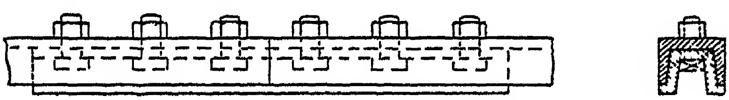


Fig 37.—Channel-rod Coupling

The Great Western Railway have adopted a scarfed coupling; this forms a good splice joint, which does not readily get loose. This is illustrated by fig. 36.

Channel and tee rodding is jointed by means of a fishplate secured with bolts in a similar way to those used for the permanent way. An illustration is given in fig. 37.

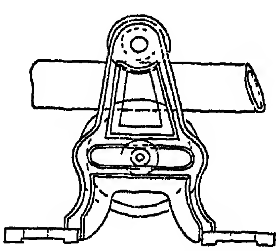


Fig. 38.—Point-rod Roller, Southern Railway (Brighton Section)

Figs. 38 and 39 show the traversing rollers used for carrying the point-rodding; they are built up of separate standards and pairs of rollers, the whole being fixed upon a stool made of 9-in. by 3-in. timber, with 12-in. top and 12-in. legs, or cast-iron trestles. A very good pattern roller, known as Haywood's

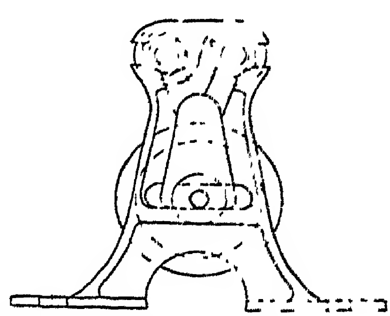


Fig 39.—Point-rod Roller, Great Western Railway

patent, which is manufactured by the Westinghouse Brake & Saxby Signal Co., Ltd., is illustrated by fig. 40. It is particularly useful where the rods have to follow a curve.

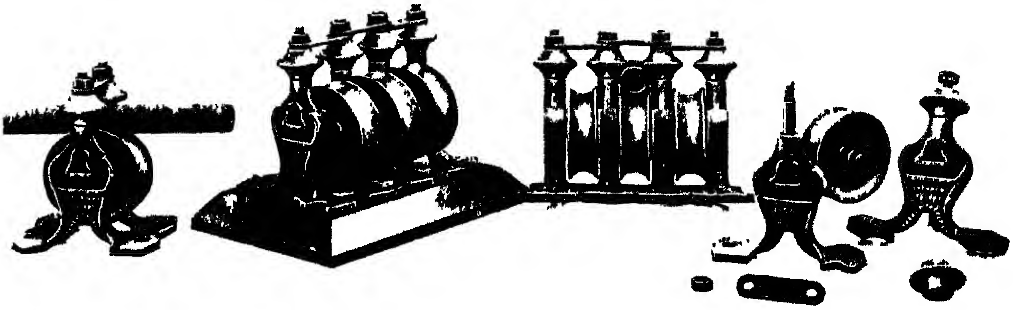


Fig. 40 —Haywood's Point-rod Roller

Signal Wires and Connections.—The signal wire most used is 7-strand No. 17 S.W.G. galvanized iron, which has a breaking strain of 1800 lb. to 3500 lb. Solid wire is also used, but not to the same extent; in this case it should be No. 8 S.W.G., which will stand a strain of about 2300 lb.

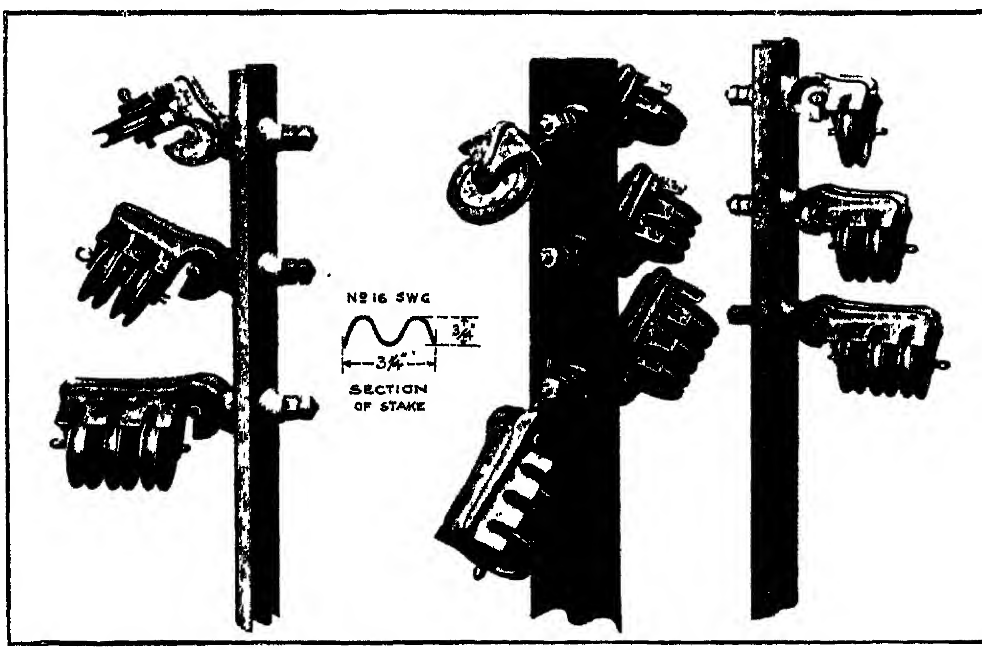


Fig 41 —Haywood's Universal Wire Pulley

The wire is connected to the chain, and joints are made by passing the end over a heart-shaped thimble and then binding it back upon itself with binding wire.

The wire should be passed over galvanized pulleys fixed to stakes,

which are driven into the ground and spaced 10 yd. apart. The pulleys may be ordinary side pulleys, where the run is in a straight line, but swing pulleys must be provided if fixed on a curve. Traversing pulleys are sometimes used, but these are not really necessary. Haywood's patent, manufactured by the Westinghouse Brake & Saxby Signal Co., Ltd., is shown in fig. 41. It may be used either as a side or angle pulley as required.

The stakes are usually of red deal, planed and painted white, or else creosoted; they are 3 in. by 3 in., and 3 ft. 6 in. to 4 ft. long. $1\frac{1}{4}$-in. by $\frac{1}{2}$-in. or $\frac{5}{8}$-in. galvanized channel-iron, and $1\frac{1}{2}$-in. by $1\frac{1}{2}$-in. by $\frac{3}{16}$-in. galvanized angle-iron stakes are sometimes used, but not to the same extent as the wooden ones.

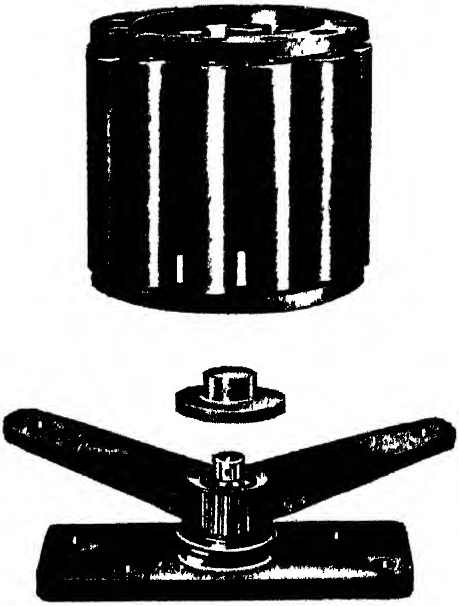


Fig. 42.—Anti-friction Bearings for Ground Connections (Tyer)

Anti-friction Bearings for Ground Connections.—Messrs. Tyer & Co. have introduced a roller bearing for use in the place of plain bearings on ground connections. The type illustrated by fig. 42 is for use with horizontal cranks, but vertical cranks, lock-bar clips, escapement cranks, compensators, train-protection bars, facing point locks, and other ground apparatus, can be fitted with bearings of this type. The bearings are provided with covers which make them thoroughly dirt and wet proof. Bearings of this kind have been found to make the work of the signalmen easier, and the necessity for frequent oiling does not arise. If they are repacked with grease once a year they will give satisfactory service.

Where the signal connections have to take a corner a horizontal pulley is fixed; this should be from 10 to 14 in. in diameter. A 5-ft. length of $\frac{1}{4}$-in. diameter chain is then joined to the wire and passed round the pulley. The wires running across the roads should run in 2-in. diameter galvanized piping laid just below the surface of the ground.

Description of Connections.—Taking the connections from the lever tail to the signal, we first require an adjusting screw; the chain then passes over a vertical pulley and is joined to the wire by means of a thimble and split link. The wire now passes over the small pulleys fixed to the stakes, and is connected to the detectors, if any; afterwards passing over a 10-in. swivel pulley at the foot of the signal, another wire adjusting screw being placed here, the chain afterwards terminating at the lever plate, to which it is attached by means of a shackle.

Taking the rodding in a similar manner, we first require a $1\frac{1}{4}$-in. solid down rod with a joint at each end; this forms the connection between the

lever tail and the 10-in. by 10-in. vertical crank; another short connection couples with the accommodating crank. These are made in three heights

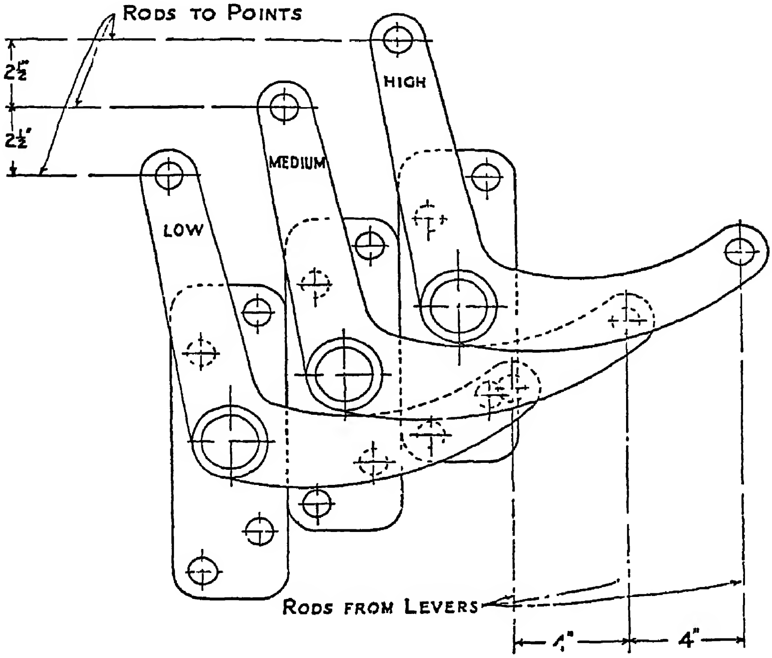


Fig. 43.—Accommodating Cranks

—low, medium, and high—as shown in fig. 43, the object being to place them close enough together to lead the rods off at 2½-in. centres. Midway in the run between the cabin and the points or lockbar, a compensator is fixed in order to counteract the effect of temperature upon the rodding; these are of several different patterns, two of which are shown in figs. 44 and 45. It is sometimes possible to fix the cranks in such a way that one half of the rodding is in tension and the other in compression, and if this is done a compensator will not be required. The last crank for leading off from the main run to the points is

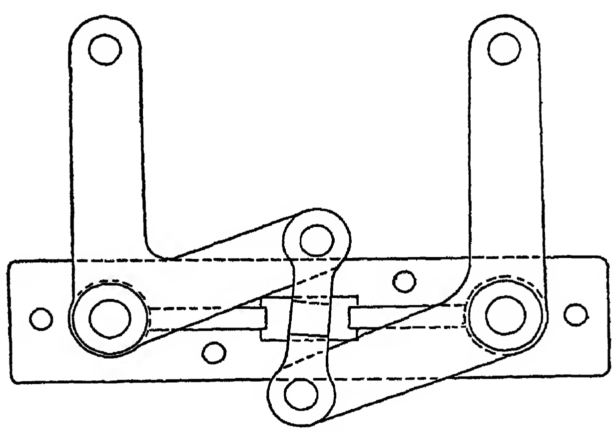


Fig 44.—Flat Compensator

made adjustable, so that the stroke may be increased if desired, as it is highly desirable to keep the movement of the rods as low as possible, otherwise the cranks would have to be much longer than those in general use. 4-in. stroke is quite sufficient to place on a 10-in. crank; it is

also about the limit for a compensator, and therefore it will be seen that some means of increasing the stroke must be provided. For this

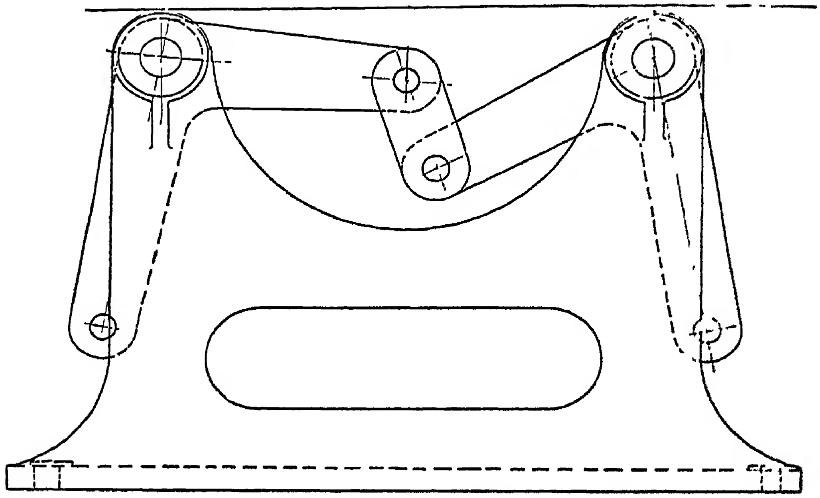


Fig. 45.—Vertical Compensator

purpose a 10-in. by 15-in. adjusting crank is used for leading off to a pair of points, and a 10-in. by 18-in. crank for a lockbar. In each case a $1\frac{1}{4}$-in. adjusting screw is placed in the cross rod.

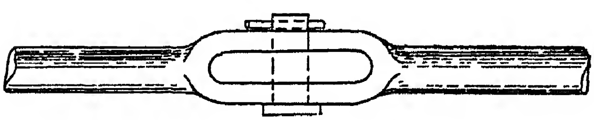


Fig. 46.—Through Joint

As a rule the points at each end of a cross-over road are worked on the same lever. A through joint, as shown in fig. 46, is then fixed at the first adjusting crank, the rodding continuing to the other pair of points. A compensator is also required in the centre. An alternative method is to fix a lug and joint instead of the through joint. This is shown in fig. 47.

Facing-point Lay-out.—Fig. 48 illustrates an ordinary facing-point

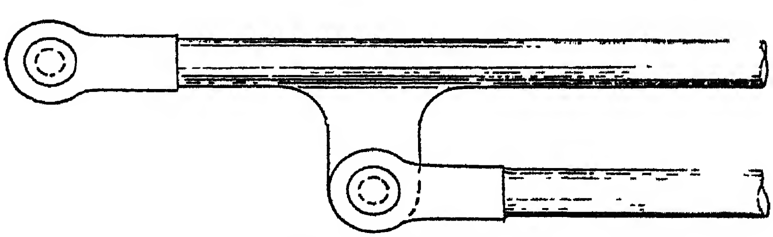


Fig. 47.—Lug and Joint

lay-out. The points are worked by means of a stretcher rod which connects both tongues, and is moved from the cabin by means of the rod attached to one of the point tongues. A pair of divided stretcher blades is connected, one to each tongue, and slide in a plunger box, two holes being cut in the stretchers into which the bolt is shot. The bolt receives its

movement from the cabin through a three-way crank, to which is also attached the lockbar. The bolt therefore cannot be put in or withdrawn without lifting the locking bar above the rails. If the bar is now made of such a length that it is longer than the wheel base of any vehicle used upon the line, it follows that as the presence of the vehicle prevents the bar from rising, the points cannot be unbolted during the passage of a train. The only possibility would be in the event of a breakage of the rod operating the bar. To obviate this the arrangement shown in fig. 49 is recommended. In this scheme the plunger bolt is operated through the bar, and therefore detects any breakage.

The locking bars are made of 2-in. by 2-in. by $\frac{3}{8}$-in. angle-iron or 2-in. by $1\frac{1}{2}$-in. by $\frac{5}{16}$-in. tee-iron, and carried by wrought-iron arms working in cast-iron clips which are bolted to the rail as shown in fig. 50. A detail of the plunger-bolt (but with solid instead of divided stretchers) is shown in fig. 51.

Signal Detectors.—Fig. 52 illustrates the most usual form of detector. A connection is taken from each tongue to a pair of split blades which slide in a transverse groove in the detector casting. The signal wires are connected to slide bars

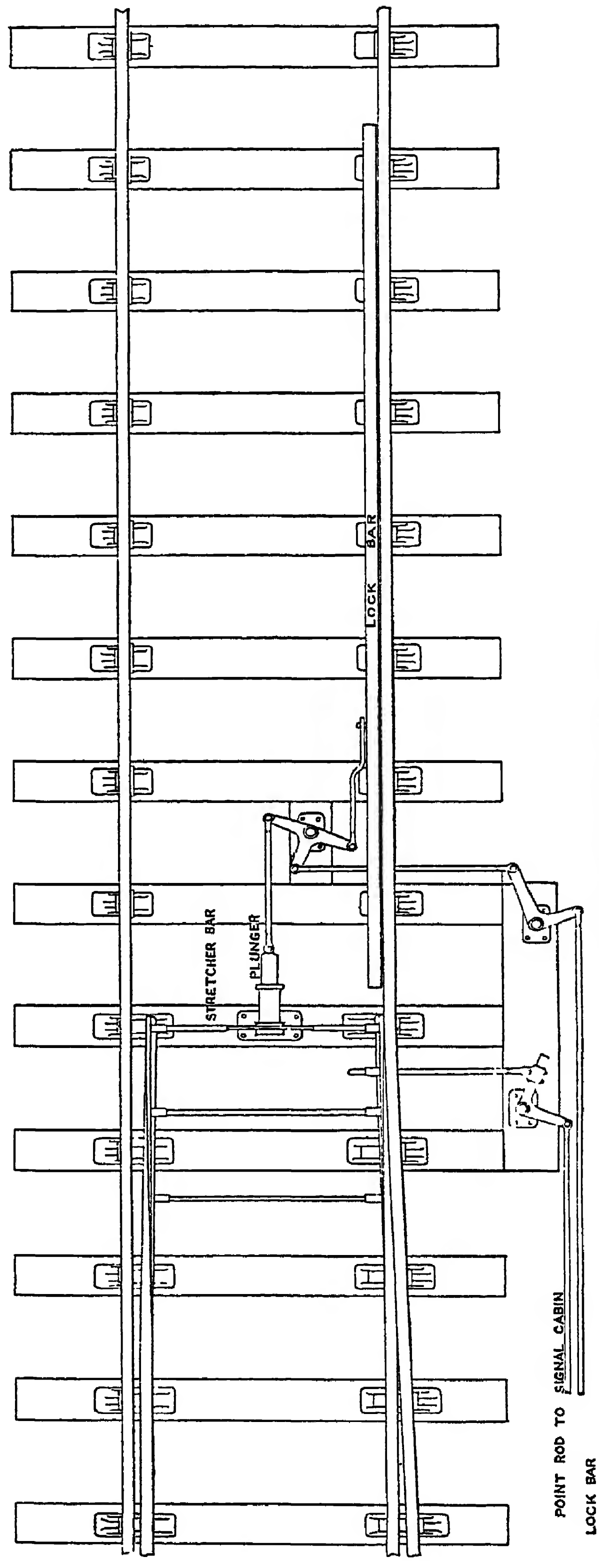


Fig. 48.—Typical Facing-point Lay-out

which move in longitudinal grooves in the same casting, and at right angles to the split blades. Projections are riveted to the under side of the signal slides, which are only free when the notches which are cut in the blades are opposite; therefore the signals cannot be lowered with the points either in the wrong position or out of adjustment.

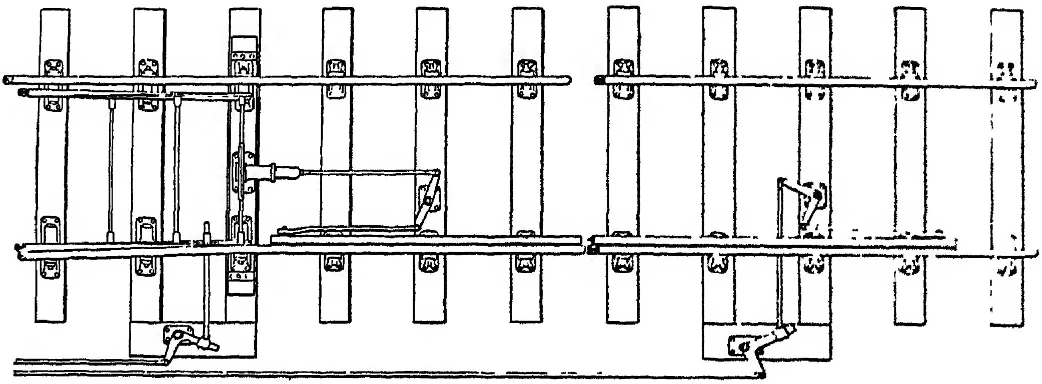


Fig. 49.—Facing-point Bolt worked by Lock Bar

A detector used on the London Midland and Scottish Railway (Lancashire and Yorkshire section) is shown in fig. 53. It is similar to the one already described, with the exception that cranks having a projection on the bosses are used in place of the signal slides.

The pattern used on the London Midland and Scottish Railway (North-Western Section) has a curved blade which works through the slots in the

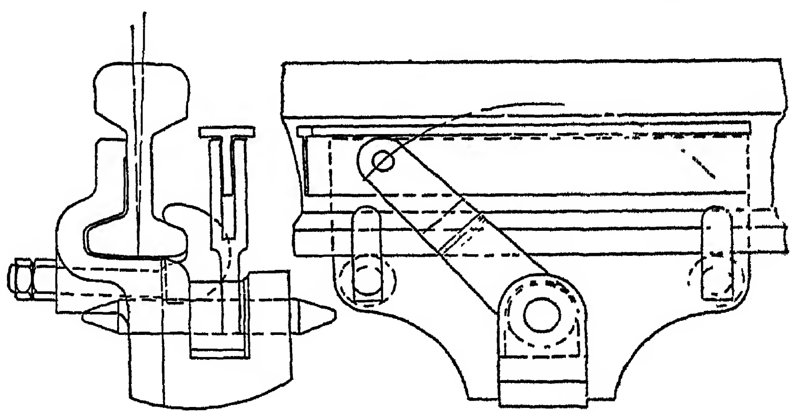


Fig. 50.—Inside Lock-bar Clip

stretcher blades. In a Great Western Railway type the movement on the signal crank imparts a downward movement to plungers which pierce the blades.

Detecting Plunger Bolt.—It is now a Ministry of Transport requirement for the signals to detect the plunger bolt, as well as the facing points. Fig. 54 shows a very simple method which is used by

the W. R. Sykes Interlocking Signal Company, Ltd., and does not involve the use of special apparatus.

Another type, which was designed by Dutton & Co., is actuated by the combined movements of the points and the bolt in a novel manner. A lug on the side of the plunger carries a sleeve which slides upon a crossbar.

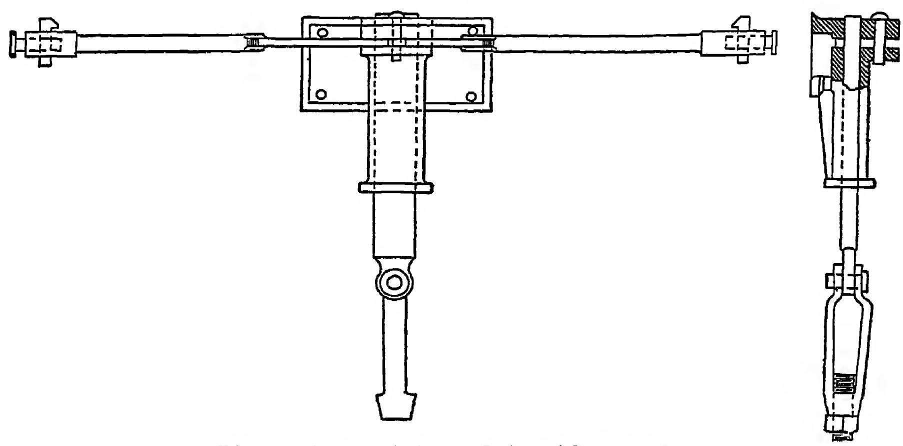


Fig 51 —Detail of Plunger Bolt and Stretcher Bar

One end of the crossbar is connected to the stretcher rod and the other to the detector blade. The long arm of the three-way crank fits into a projection riveted to the lockbar, thus locking the bar down in its two lowest positions.

Griffith's detector and facing-point lock is illustrated by fig. 55, and is manufactured by Westinghouse Brake and Saxby Signal Co., Ltd. The main feature of this contrivance is the dog lock, shaped thus ⊓, which rides up and prevents the crank which is attached to the stretchers from passing over it, and consequently from operating the detector slide until the bolt is properly home in the stretcher blades.

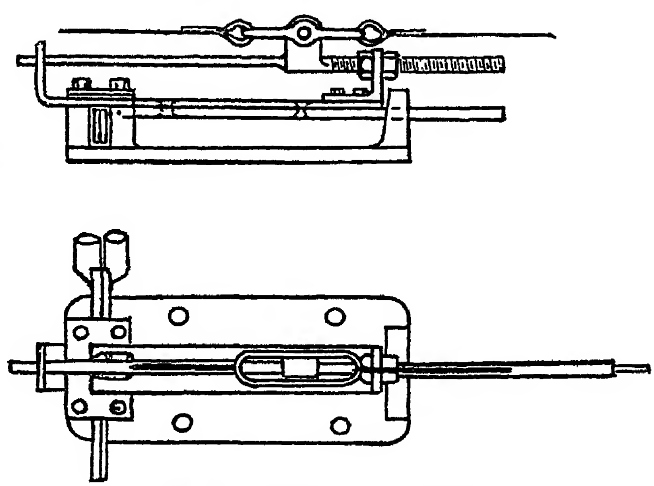


Fig. 52.—Mechanical Point Detector

Electrical Detection.—Detection of point tongues and plunger bolts by electrical means possesses considerable advantages, as it does away with the finely set mechanical detector and the attendant troubles due to want of adjustment. Contact slides are connected directly to the ends of the point tongues by short lengths of rod, and unless the points are in position within fine limits, the contacts are not closed and electric locks on the respective signal levers cannot be lifted to release the signal lever. The

importance of first-class wiring and cabling cannot be over-emphasized on work such as this. Polarized detection relays are favoured as they decrease the possibility of a release being obtained owing to contact with a live electrical circuit. (See Chapter XV.)

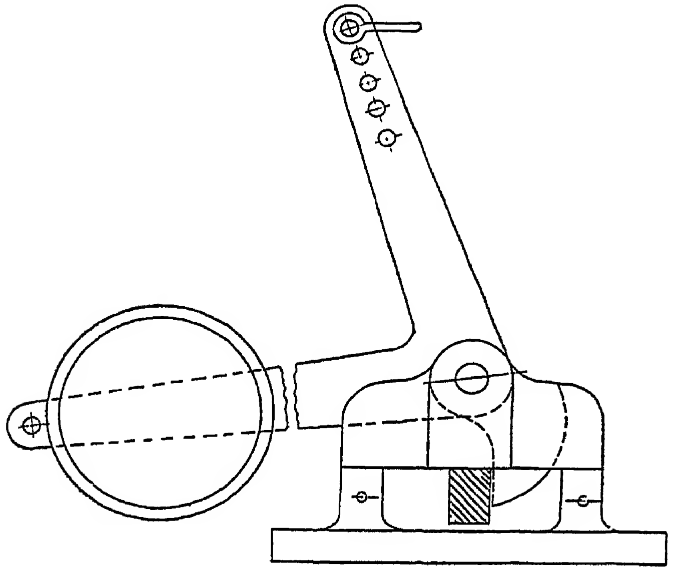


FIG. 53.—Detector, London Midland and Scottish Railway (L. & Y. Section)

Scotch Blocks.—Fig. 56 shows one form of scotch block which is used in some cases in place of a pair of trap points. It is moved on and off the rail by means of a rod connection in a similar way to a pair of points. The main portion is made of cast iron, and the block itself reinforced with wrought-iron cheeks.

Reversers.[1]—It is sometimes necessary to throw a signal to danger, when passed by a train, independently of the signalman. Although there are well-tried electrical appliances on the market for attaining this object, some engineers prefer a mechanical contrivance. An arrangement of this kind is manufactured by the W. R. Sykes Interlocking Signal Company,

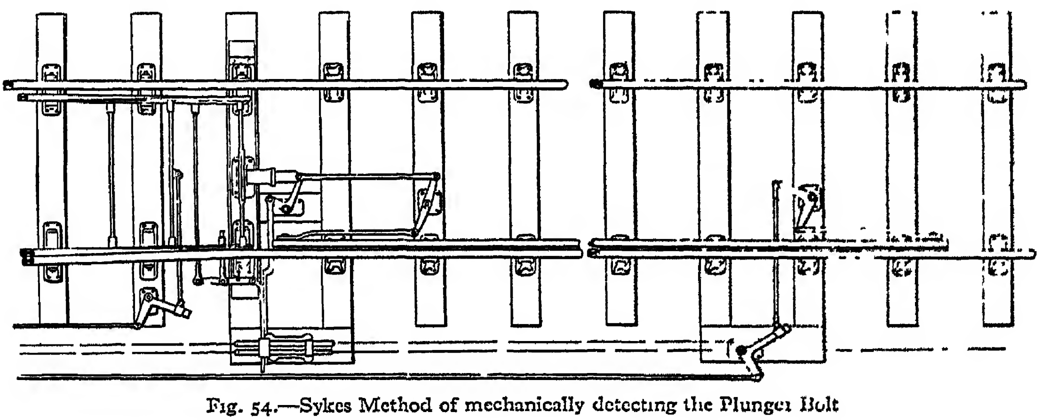


FIG. 54.—Sykes Method of mechanically detecting the Plunger Bolt

Ltd. It is connected up as follows. The wire from the cabin passes over a draft wheel fixed on the balance lever of the signal, afterwards continuing over a swivel wheel fixed at the foot of the post to the treadle, which is fixed about a train's-length ahead. It is then attached to one end of the

[1] Also known as "replacers".

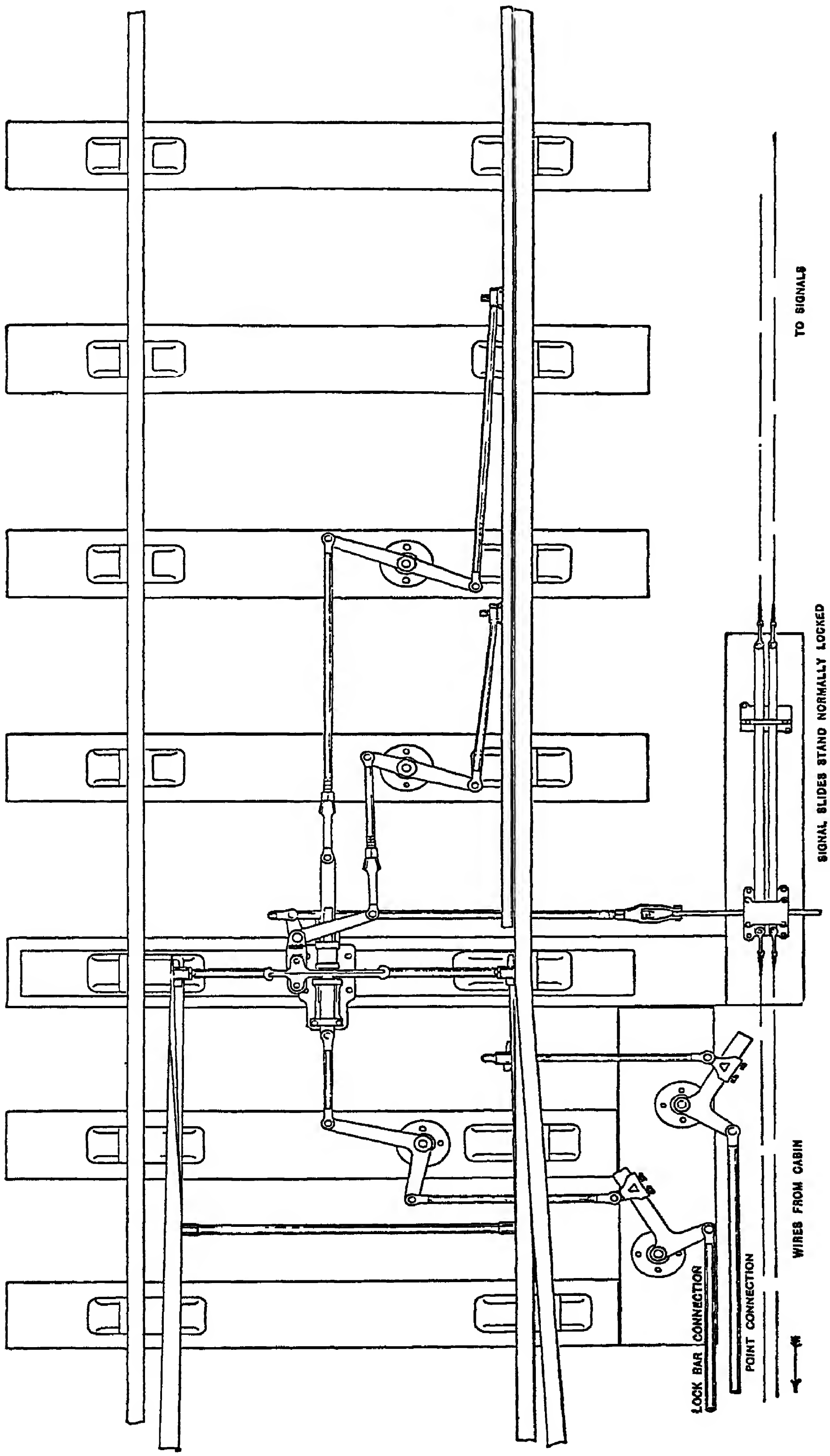


Fig 55.—Griffith's Facing-point Lock and Bolt Detector

slide, the other end being connected by a chain which passes over a wheel and terminates in a weight. The slide bar is prevented from moving by a trigger which normally stands above the rail. This trigger, when depressed by the first wheel of the train, allows the slide to run back, which slackens the wire, and allows the signal to fly to danger. It may be mentioned that the slide when released holds the trigger down until the lever in the cabin is placed in its normal position, thus preventing the successive depressions which would otherwise occur as each wheel passed over it. The signal cannot be lowered a second time unless the lever is replaced and pulled a second time.

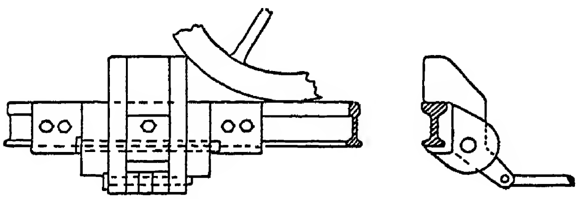


Fig. 56 —Scotch Block

Slots.—At this point we may consider the different devices for giving two or more signalmen the control of one signal. It requires the joint action of the signalmen to lower the signal, but either man may throw the arm to danger by replacing his lever. These arrangements are commonly known as slots.

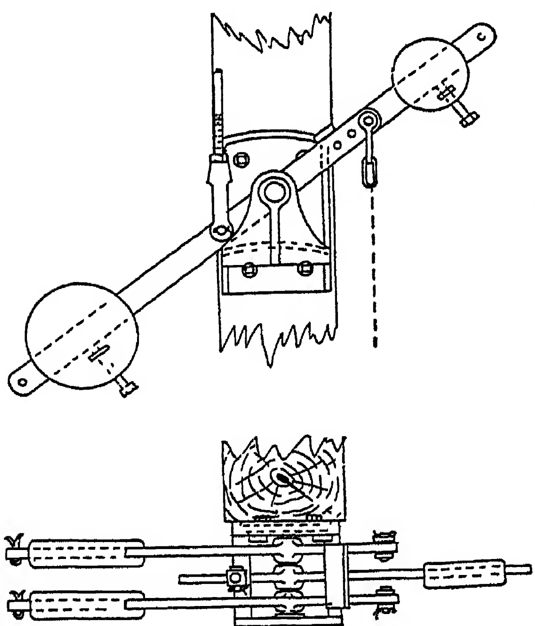


Fig. 57 —Drop-off Slot

Fig. 57 shows a simple form of "drop-off" slot such as would be used on a post having a home signal with a distant arm underneath, the home being worked from cabin A and the distant from cabin B.

Three levers are carried in a casting fixed to the signal post; one is connected by a wire to cabin A and the home arm, the middle lever is connected to the distant arm, and the outside lever to cabin B. When A pulls his lever the home signal is lowered. B now pulls his distant lever, which moves the outside lever on the post, this in turn allowing the centre lever to fall and lower the distant arm. If, however, A replaces his lever the home signal goes to danger, and carries the centre lever with it, thus throwing the distant arm to danger also. The weights must, of course, be arranged so that the levers connected with the cabins are more heavily weighted than the one connected with the distant arm.

Selectors.—Levers in the cabin may often be saved by working

several signals on one lever. Fig. 58 shows a hook selector which is used for this purpose. The signal wire from the cabin is connected to the hook slide, and the wires to the signals are attached to the selecting slides. A rod is connected between the tongue of the points and the hook in such a manner that in one position of the points the hook slide is in connection with one selecting slide, and in the reverse position of the points with the other slide.

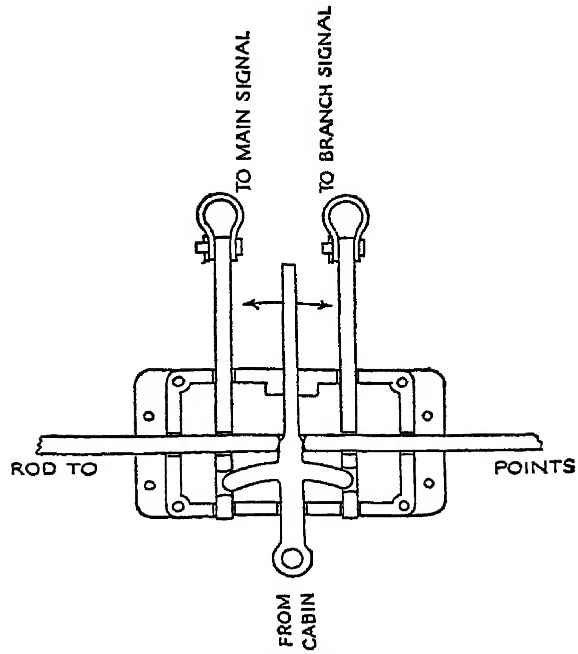


Fig 58.—Mechanical Hook Selector

Protection of Ground Connections.—As a means of protecting the facing-point connections from being torn up by long wagon couplings, or hanging brake trimmings, it is a good plan to fix some sort of covering. One way is to provide a hinged box with a ramp at each end, or the arrangement shown in fig. 59,

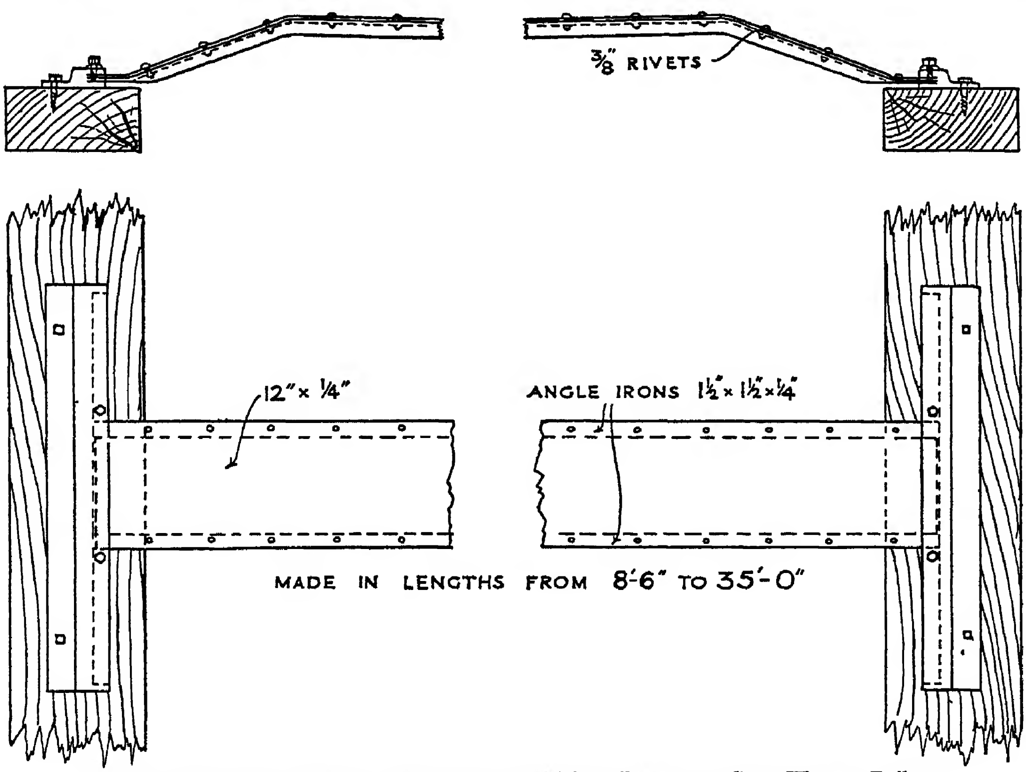


Fig. 59.—Cover for Facing-point Lock, late Taff Vale Railway, now Great Western Railway

which is the style adopted by the late Taff Vale Railway, now Great Western Railway.

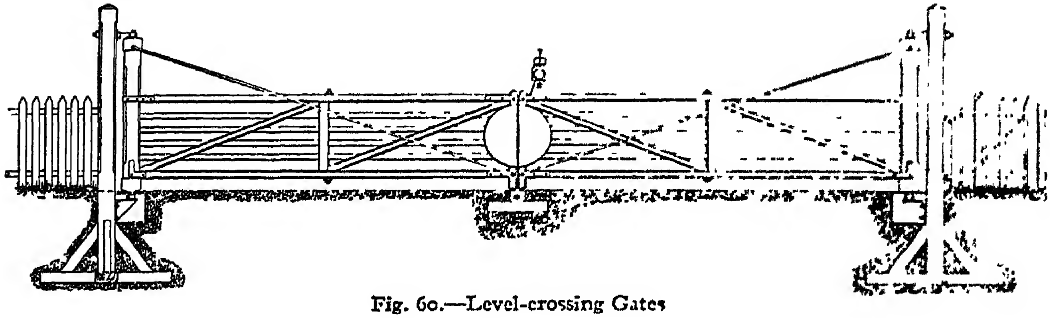


Fig. 60.—Level-crossing Gates

All places where rods and wires are exposed should be covered in to prevent the possibility of guards and shunters tripping over them. The easiest way of dealing with wires is to run them in 2-in. diameter piping or wood troughing. The rods and connections should be boxed in, the top covers being made in detachable sections.

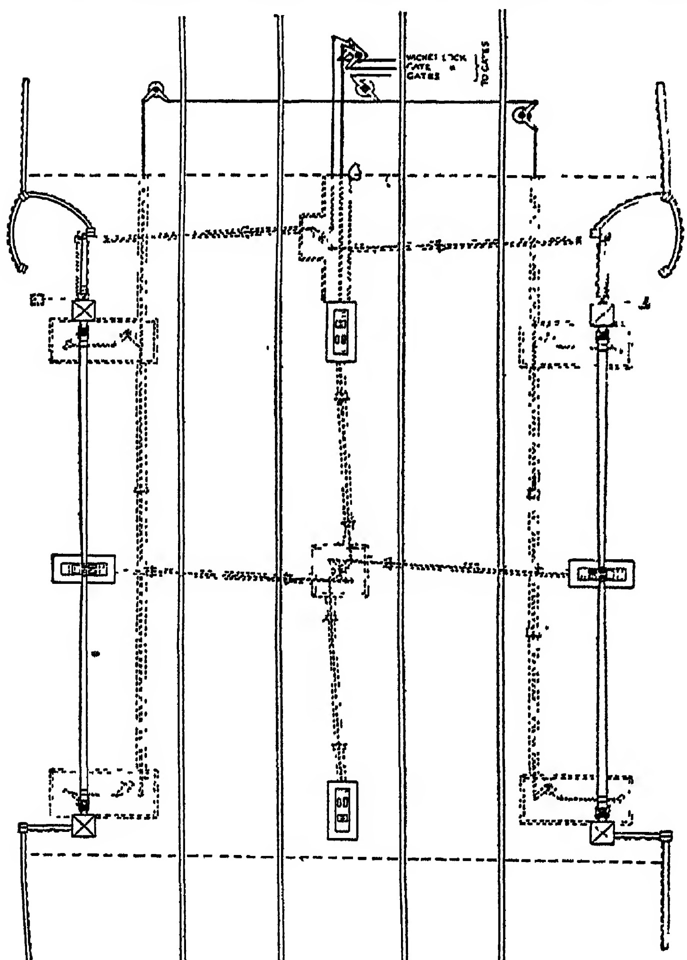


Fig. 61.—Diagram of Gate Connections

The Southern Railway (Brighton Section) have a very neat way of covering a run of rods. Special roller standards, having lugs cast on, are fixed on the outside rods. Cast-iron ⊔-shaped grids, which support the covering timbers, are then bolted to the special roller standards.

At level crossings and other places where heavy traffic crosses the railway the point rods should be run in cast-iron troughing.

Timber frames are generally used for carrying the various cranks, compensators, pulleys, point-rod rollers, &c., already described. Iron

frames and trestles are more suitable for this purpose and are rapidly displacing the former. Ferro-concrete is also used considerably.

Level-crossing Gates.—All gates must be made to open inwards towards the railway. They may be operated by hand or from the cabin, but in any case they must be interlocked with the signals. Wicket gates should be provided for the use of foot passengers (unless an over bridge already exists), and should be weighted and interlocked with the signals by a lever in the cabin.

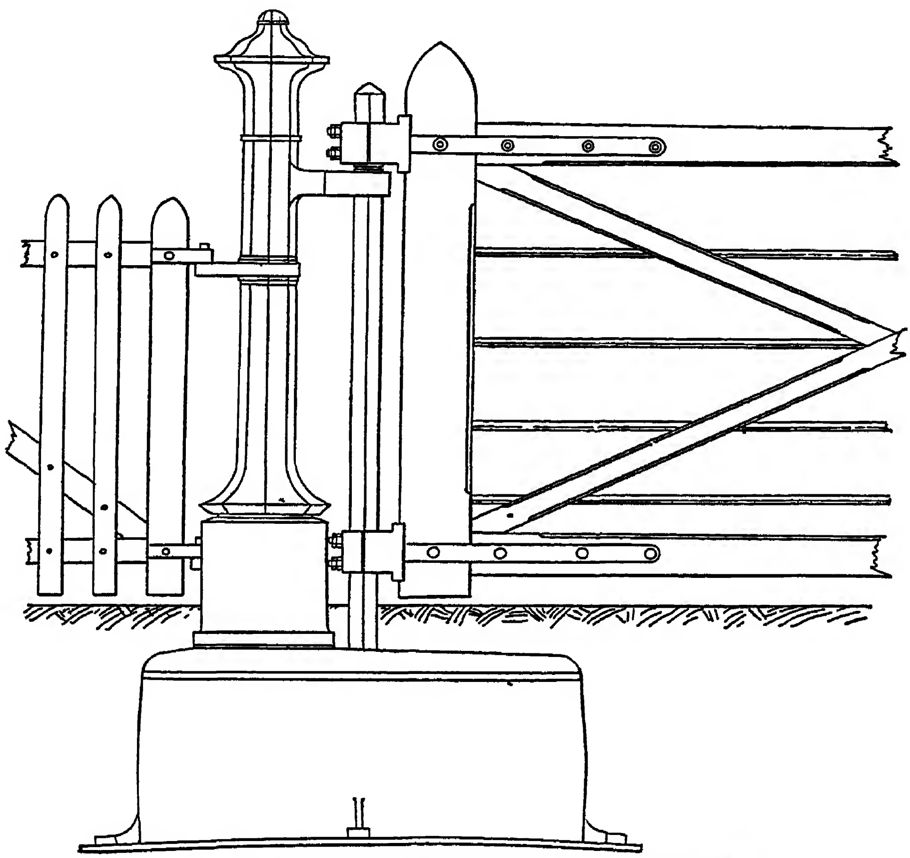


Fig. 62.—Cast-iron Hanging Post for Level-crossing Gates

Fig. 60 illustrates a pair of main gates with a wicket gate at the side. The main gates are of oak, 5 ft. high from the ground, and are hung from a 12-in. by 12-in. post, and fixed into the ground with a crossing and spurs. An iron target, which is painted red, is provided for showing the road users when the gates are closed against them during the day-time, and a lamp which gives a red light during the night-time.

The lower portion of the gate is covered with a large-mesh wire netting. Provision must be made for adjusting and taking the weight of long gates by means of a diagonal tie-rod and adjusting screw. The gate heels should also be adjustable.

Stops are provided for holding the gates in position. They are four in number and worked on one lever in the cabin, two being raised whilst the other two are lowered. Fig. 61 is a diagram of the connections. The gate crab is normally locked and the gates secured in position across the roadway by means of the stops which are raised. The first movement is to pull the stop lever to the first notch, thus lowering the road stops and raising the rail stops in readiness to receive the gates. The crab is now free, and the gates are closed against the line, a projection on the end of each gate passing over the inclined stop, which is pressed down, allowing the gate to ride over it, afterwards rising and holding it in position. The stop lever is now free to be moved fully over, which locks the stops in the raised position and backlocks the gate crab.

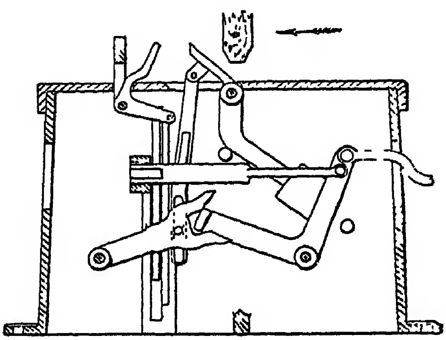


Fig. 63 —Gate Stop

In cases where the width of line exceeds that of the roadway the gates must be arranged to overlap when closed against the roadway. It will therefore be necessary to operate two of the gates in advance of the other two, either by working them on a separate crab or providing some suitable escapement gear.

The late Messrs. M'Kenzie & Holland manufactured the gates shown in fig. 62. The hanging posts are of cast iron fixed upon an iron pan which contains the centre for a square shaft. The shaft carries a crank by which the gate is operated.

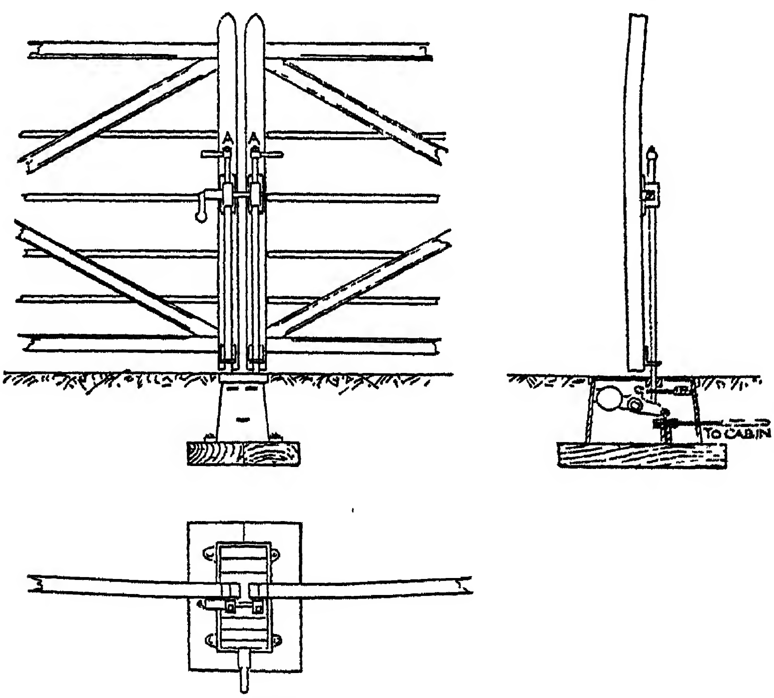


Fig 64.—Gates worked by Hand, and mechanically locked from Cabin

The detail of the gate stop shown in fig. 63 is also Messrs. M'Kenzie & Holland's type.

$1\frac{1}{2}$-in. solid rodding is to be recommended for working the gates in

preference to chains. It should be carried in cast-iron trunking below the ground where the connections cross the roadway.

Control of Gates.—In cases where the gates are opened and closed by hand they must be secured by a latch or other means, and an arrangement fitted to prevent the latch from being dropped until the gate is closed.

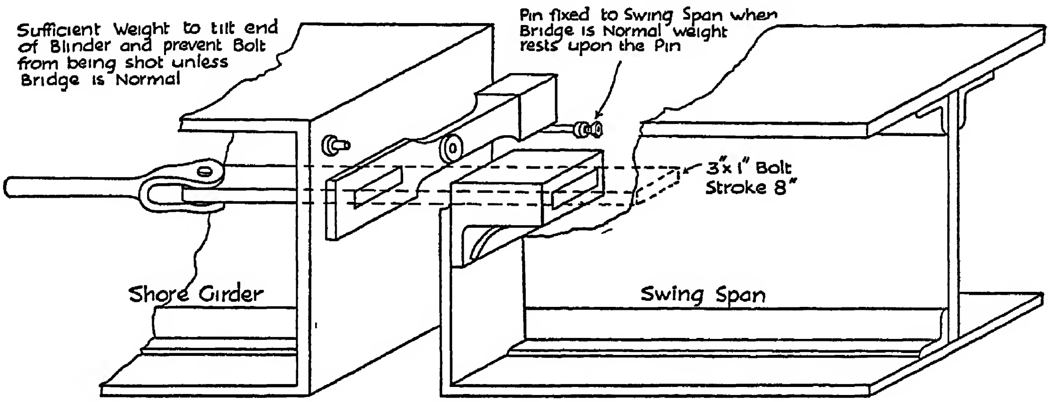


Fig. 65.—Bridge Bolt

The controlling lever in the cabin is then placed normal, which locks the latch and prevents it from being raised. Fig. 64 illustrates one method of doing this. Another arrangement is to fix a contact on the latch and an electric lock on the stop lever in the cabin. The signalman is therefore unable to place the lever normal until the gates are shut and bolted.

Swing Bridges.—Under this heading we may take any movable bridge, whether a swing, roller-lift, or bascule bridge.

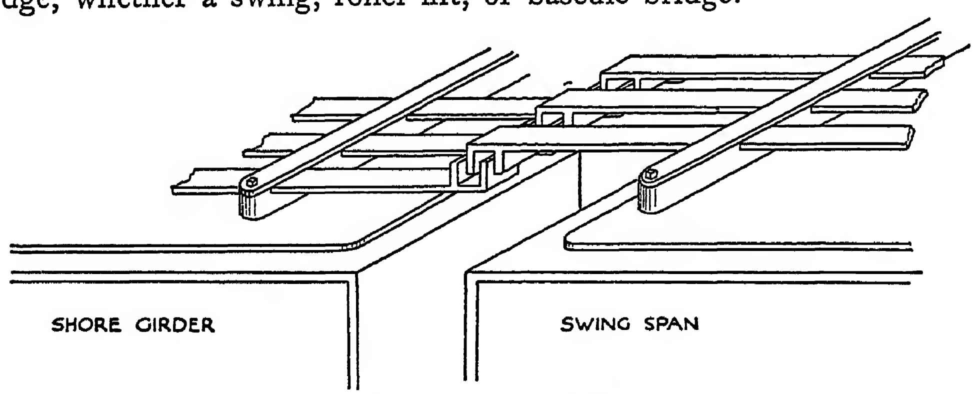


Fig. 66.—Bridge Disengager

The cabins may be placed on the swinging span of a swing bridge, but in the cases of roller-lift and bascule bridges they must of necessity be placed on the shore. The only extra lever required in the signal box will be for operating the bolts. This lever should release the mechanism in the power house for withdrawing the wedges and swinging or lifting the bridge.

When in the normal position the ends of the moving span and the centre rest on wedges. The first operation, therefore, after withdrawing

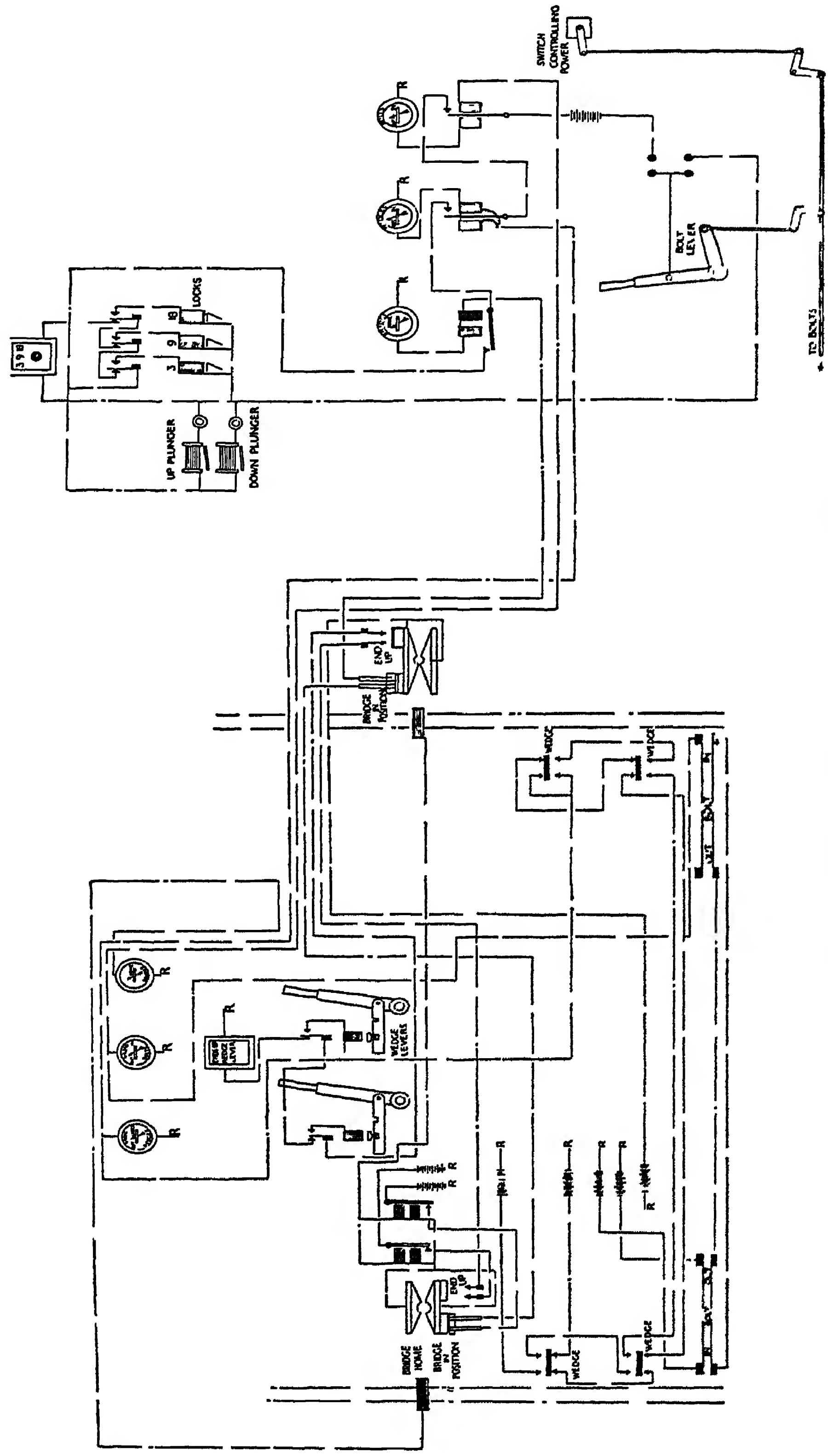


Fig. 67.—Locking and Indicating Circuits for Swing Bridge

the bolts, is to raise the bridge; this is usually done by means of hydraulic rams. When it has been raised about 3 in. the wedges are withdrawn; the bridge is now lowered on to its centre and is ready to be swung.

Arrangements must be made for disconnecting all signal and point connections automatically with the movement of the bridge. The bolts should also be backlocked so that they cannot be shot until the bridge has been restored to its normal position and the wedges replaced. It is also an advantage for the bolt lever to cut off the power from the power house, which can easily be done when electrical power is used.

Fig. 65 illustrates the bolt. It will be noticed that a weighted blade falls in front of the bolt directly the stud which is fixed on the moving span begins to move. This is one means of backlocking the bolt.

Fig. 66 shows one way of disengaging the signal and point connections. A flat box containing a number of slides which have upturned hooks is placed on the shore girder, and a similar arrangement, but having down-turned hooks, is fixed on the swing girder. As the bridge swings, these hooks are automatically disengaged. Ordinary tappet locks may be placed in the slides to lock them when disengaged, otherwise the jarring of the bridge might move them enough to prevent their proper engagement afterwards.

The movement of the rods should be kept as small as possible, and gain-stroke levers fixed on the other side of the bridge where the connections are changed from rodding to wire connections. Wire adjusters should also be provided in order to make adjustments as necessitated by the weather.

Fig. 67 is a general arrangement of the connections. The indications in the signal box showing "bridge up", "bridge down", "bolts in", "bolts out", "wedges under", and "wedges out", are preferably electrical, as it is practically impossible to adjust mechanical indicators to the nicety required.

CHAPTER V

Examples of Two- and Three-position Signalling

British Mechanical Signalling (Two-position).—When new signals are being put down, or existing ones altered, the representatives of the various departments concerned should meet on the ground and decide upon the position of the cabin. The signals should afterwards be sighted and the heights agreed upon. The plan should then be signed by the officials concerned before the work is commenced.

A very good apparatus for sighting signals consists of a number of bamboo poles in 5-ft. sections, each section being made to fit into the next by means of a socket. A few lengths may be fixed up and a red flag attached

at the top, this height being then judged from a distance to see the effect of the background. It should be remembered that the signal ought always to be considered from the driver's point of view—that is about 9 ft. from rail level—and very often a signal which shows up clearly against a sky background when viewed by a person standing at rail level, would come perhaps right in front of a row of brick houses when seen from the footplate of an engine. To get over this difficulty a periscope is sometimes used and should prove very useful. Messrs. Sykes signal sighting apparatus is shown in fig. 68. It is a good plan to set out the positions of the cabin, signals, and points by means of wooden pegs. This saves confusion afterwards, and it also allows the chargeman to commence laying down his connections immediately.

Fig. 68.—Sykes Signal Sighting Apparatus

As a rule the plan is sent into the drawing office, where the quantities of material are taken out and the particulars of heights of signals, colours of levers, descriptions for name plates, &c., are made out and sent into the shops.

Locking Tables.—The next step is to prepare a table of locking. In doing this safety should be the first consideration, and freedom of working the second.

Fig. 69 is an illustration of a small station, with a table of locking given below. The points should be interlocked if possible, as by so doing much locking may be saved on the signals. Only the ordinary releases are shown in the table; for instance the distant signals are preceded by the homes and starters, and therefore these signals cannot be placed at danger until the distant is first put to danger.

The signals in advance of points should always, if possible, lock the trailing points in the normal and reverse positions.

A simple junction is shown in fig. 70. This shows the use of fouling bars to ascertain when the tail end of a train is clear of the junction. The facing points on the down line are worked by No. 9 and locked by No. 8, which, of course, also works the lockbar. No. 10 works the trailing junction points in the up line, and these points should always be preceded by

No. 9 in order to divert a train to the branch line in the case of its overrunning the junction signal.

The facing points stand normally unlocked, that is to say, the lever in the cabin has to be pulled in order to lock the points and therefore to release the junction signals. It is the practice on some lines, however, to lock the points normally, in which case the lock lever has to be pulled first, the points then moved, and the lock lever put normal to lock them in their new position. In these circumstances the signal levers must lock the lockbar lever.

Fouling bar No. 11 has to be moved before Nos. 2 and 13 signals can be given, and No. 7 before signal No. 5 can be lowered.

A diagram of the mechanical locking is given in fig. 71; it is actually the locking given in the table in fig. 69, and is so simple that an explanation is hardly necessary, but it may be mentioned that it has been laid out more with a view of showing the different types of locks and their combinations than of saving space.

Distinguishing Marks on Levers: Contracts for Work.—The levers are painted in distinctive

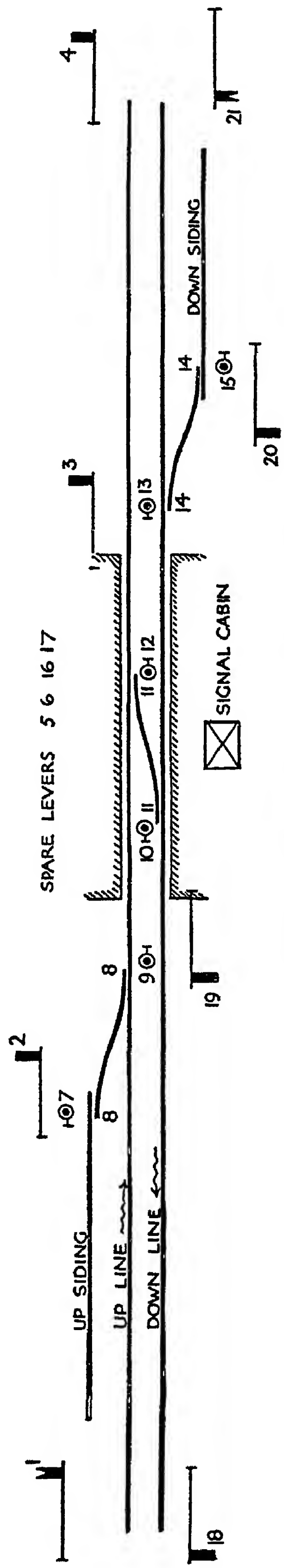


Fig 69 —Diagram and Locking Table of Simple Wayside Station

No	Description.	Released by	Locks	No	Description	Released by	Locks
1	Up Distant Signal	2, 3, 4	—	12	Disc· Up to Down Line	11	3, 10
2	Up Home Signal	—	8, 11	13	Disc· Down Line to Down Siding	14	15, 19
3	Up Starting Signal	—	9, 12 (8, 11 B, W)	14	Points	—	11, 20
4	Up Advanced Starting Signal	—	—	15	Disc Down Siding to Down Line	14	13
5	Spare	—	—	16	Spare	—	—
6	Spare	—	—	17	Spare . .	—	—
7	Disc· Up Siding to Up Line	8	9	18	Down Advanced Starting Signal	—	—
8	Points	—	2, 11	19	Down Starting Signal	—	10, 13 (11, 14 B/W)
9	Disc Up Line to Up Siding	8	3, 7	20	Down Home Signal .	—	11, 14
10	Disc· Down to Up Line	11	12, 19	21	Down Distant Signal	18, 19, 20	—
11	Points	—	2, 8, 14, 20				

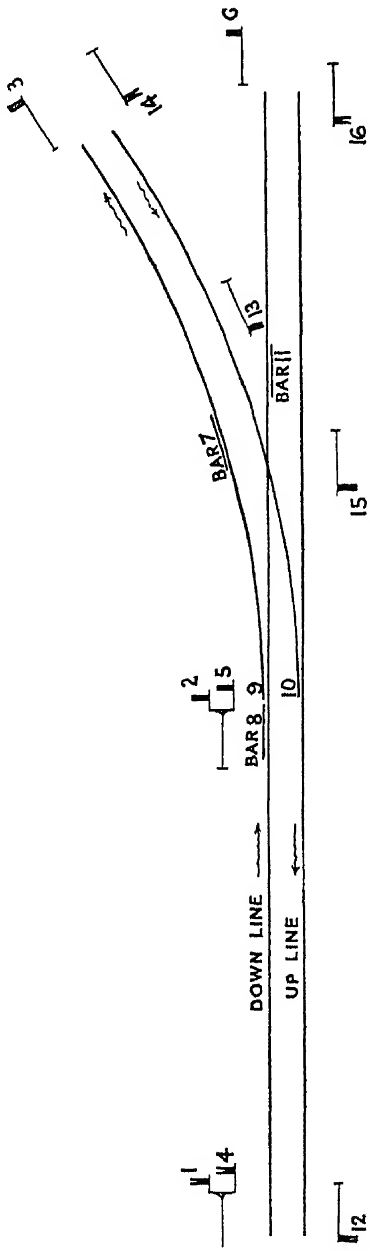


Fig 70.—Diagram showing Use of Fouling Bars at a Junction

colours according to the work which they perform; the following are the colours mostly used:

Points—Black.
Shunting and stop signals—Red.
Distant signals—Green.
Gong lever—Yellow.
Gate locks and facing-point locks—Blue.
Spare levers—White.

Labels are attached to the levers and bear the description of the work performed, and also the numbers of preceding levers. They may be of cast iron with raised or painted letters, or of brass with engraved letters.

A diagram of the roads and signals should be provided and hung up in a conspicuous position for the guidance of the signalman. The type of diagram is a matter of opinion, but many consider the single-line is clearer than the double-line type; an example is given in fig. 72.

Most railway companies now carry out their own work, either purchasing the material in quantities from the manufacturers or making it up themselves. Some companies, however, still prefer to let the work out to contractors, the works afterwards being measured up on a schedule of prices or paid for in a lump sum according to the contract plan, and additions or deductions based upon the schedule.

On p. 50 is a sample page showing how a schedule can be drawn up. It should be accompanied by a specification, but space will not permit of its being set out in these pages.

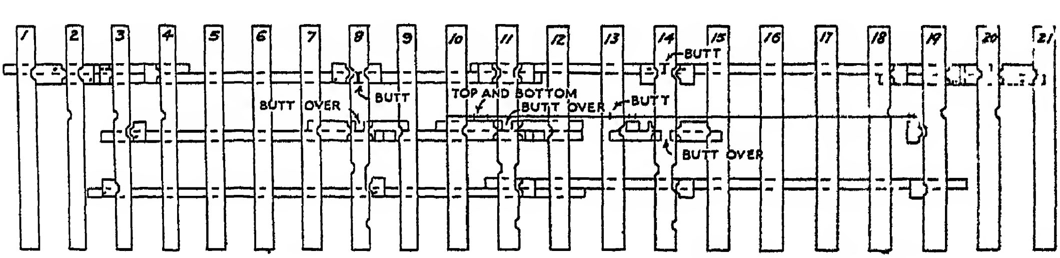
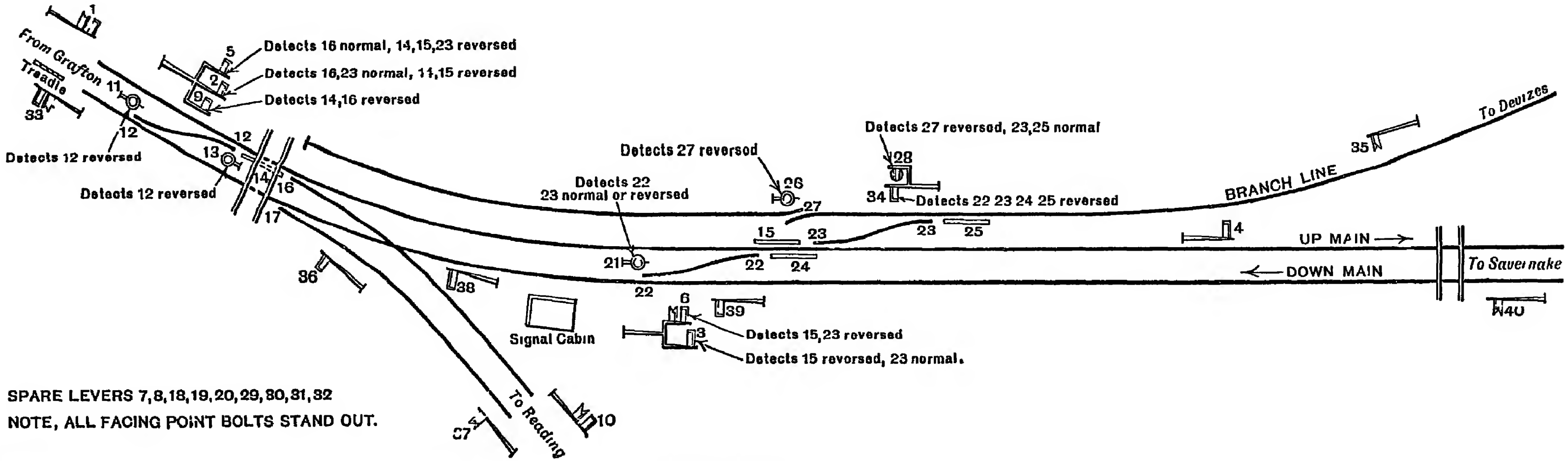


Fig. 71.—Diagram of Locking



SPARE LEVERS 7,8,18,19,20,29,30,31,32

NOTE, ALL FACING POINT BOLTS STAND OUT.

MECHANICAL LOCKING

No	Description	Released by	Locking.	No	Description	Released by	Locking.
1	Signal Up Main Distant	2, 3, 4	—	22	Points Up Main to Down Main or Facing Branch to Down Main	—	12, 15, 17, 39
2	Signal Up Main Home	14, 15	12, 16, 23	23	Points Facing Up Main to Branch	—	2 3, 16, 27
3	Signal Up Main Starting	14, 15	(12 B and F), 13, 16, 23	24	Facing Point Lock on No 22 Points	22	—
4	Signal Up Main Advance	—	(15, 22, B and F)	25	Facing Point Lock on No 23 Points	23, 24	15, 21
5	Signal Up Devizes Branch Home	14, 15, 23	12, 16	26	Signal Shunt from Dead End	27	28
6	Signal Up Devizes Branch Starting	15, 23	(12 B and F), 13, 16	27	Points Catch	—	23
7	Spare	—	—	28	Signal Shunt to Dead End	27	26
8	Spare	—	—	29	Spare	—	—
9	Signal Up Reading Branch Home	14, 16	12	30	Spare	—	—
10	Signal Up Reading Branch Starting	—	13	31	Spare	—	—
11	Signal Shunt Down to Up Main	12, 14	13, 33	32	Spare	—	—
12	Points Crossover Up Main to Down Main	—	2, 5, 9, 22, 36, 38, 39	33	Signal Down Main Advance	—	11, (12, 17 B and F)
13	Signal Shunt Up to Down Main	12	3, 6, 10, 11	34	Signal Home from Devizes Branch	25	—
14	Facing Point Lock on No 16 Points	—	(16 B and F)	35	Signal Distant from Devizes Branch	33, 34, 38	—
15	Facing Point Lock on No 23 Points	—	22, 25, (23 B and F)	36	Signal Home from Reading Branch	17	12
16	Points Facing Up Main	17	2, 3, 5, 6, 12, 23, 38, 39	37	Signal Distant from Reading Branch	33, 36	—
17	Points Trailing Down Main	—	22, 38, 39	38	Signal Down Main Inner Home	—	12, 16, 17, 21, (22, 25 B and F)
18	Spare	—	—	39	Signal Down Main Outer Home	—	12, 16, 17, 22
19	Spare	—	—	40	Signal Down Main Distant	33, 38, 39	—
20	Spare	—	—				
21	Signal Shunt Up to Down Main or Branch	22	(23 B and F), 25, 38				

Fig 72 —Diagram of Signals, Wolfhall Junction

Schedule of Prices and Bill of Quantities

The prices are for labour and materials for temporary and permanent Works, the whole of which is to be executed to the satisfaction of the Engineer, and in accordance with the Patterns, Drawings, and Specification. The whole of the items are to be priced out, whether quantities are given or not, and any additions to, or deductions from, the following quantities in the execution of the Works will be measured up according to the rates given. Only the *net* quantity of work fixed will be measured up and paid for.

Item No.	Quantity.	Item.	Rate
		Signal Cabin .. . ft. . .... in. by .... . ft . .... in. inside, with floor .... . ft. .. ... in above rail level, complete with all furniture as per drawing and specification	
		Additions to, or Deductions from, Cabin, if Necessary	
		Excavations not exceeding 4 ft. deep per cubic yard	
		Excavations below 4 ft. deep ,,	
		Do. extra in rock .. ,,	
		Portland cement concrete .. ,,	
		Blue lias lime concrete .. ,,	
		Brickwork in mortar .. ,,	
		Do. cement .. ,,	
		Locking apparatus, working levers .. each	
		Do. spare levers .. ,,	
		Ground frame, working levers .. ,,	
		Do. spare levers .. .. ,,	
		Add levers to existing apparatus and provide all necessary locking .. .. each	
		Bring existing spare levers into use and provide all necessary locking .. each	

Three-position Signals.[1]—Signals having three positions of the semaphore arm were used in the early days of signalling in connection with time-interval working in order to indicate the amount of time that had elapsed since the passage of a train. The usual practice was to exhibit a stop signal for a certain time after a train passed, then a caution signal for another interval, after which the proceed indication was given, the signal working as shown in fig. 73. With the introduction of block working only two indications were required and the vertical or concealed position of the arm was abandoned, the caution becoming the proceed position. Three-position semaphores have also been used to a great extent in the United States in connection with the train-dispatching system, the caution indication being used when it is desired to allow a train to enter an already occu-

[1] It is now proposed to use the expression " Three-aspect Signals ".

pied block section, under permissive rules. In recent years, however, three-position signals have been extensively adopted in connection with modern track-circuit and power interlocking installations, where they offer peculiar advantages for facilitating the traffic, owing to the readiness with which they can be combined to convey the various indications required. The three-position signal, as now known, originated in an attempt to make one semaphore serve the place of the two that had previously been necessary in automatic block systems where each block signal carried a distant signal under it for the next one, a semaphore moving from 0° to 45° and then to 90° downwards, displaying red, green, and white lights,[1] being employed (fig. 74). Subsequently an upper quadrant arm was adopted instead of the lower quadrant, and this practice is now practically universal with three-position signals. With the original system there were thus only three indications, viz. "stop", "proceed, expecting to find next signal at stop", and "proceed"; but attempts made to use the second indication for other purposes led to its being defined simply as "proceed with caution", which is a rather indefinite statement.

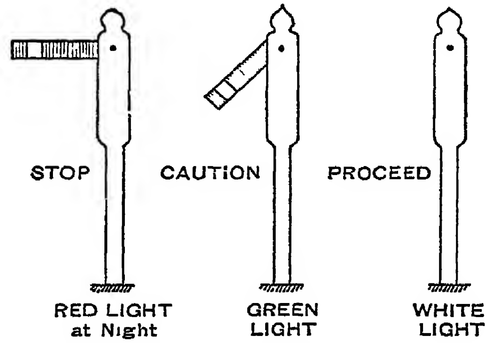


Fig 73 —Old Time-interval Signal

The chief advantage of the three-position signal is that it enables the condition of the signals ahead, and therefore the track, to be indicated in a much clearer way to the driver than is possible with two-position signals. This enables better traffic regulation to be realized.

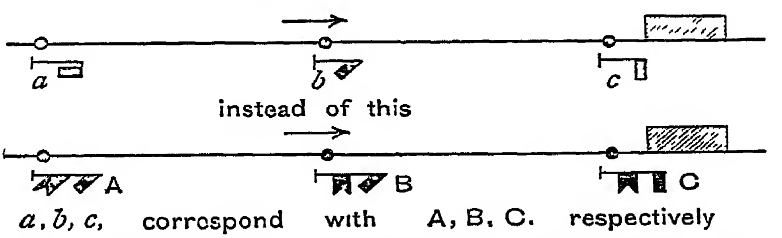


Fig 74.—Original Three-position Automatic Block System, Pennsylvania Lines West, U.S.A.

There are no very extensive three-position signal installations in Europe, except on the Belgian State Railways, where the signals are mechanically operated, but in the United States numerous large ones are to be found, which are power-operated. Power operation is essential if automatic track control and similar refinements are required, but it is not essential to the operation of signals to three distinct positions. It is obvious that

[1] Red, yellow, and green lights are now used almost everywhere in three-position signals, replacing red, green, and white, except on the Chicago and North Western and New South Wales Railways, which use neither white nor yellow lights, but only red and green.

colour light-signals can be used in place of semaphores in three- as in two-position signalling, but as a colour light-signal does not give its indications by the position of a moving member but merely by the colour of its lights it is better to speak of three- or two-aspect signals when referring to this type. It should be pointed out that the adoption of the three-position or three-aspect principle for any installation does not imply that every signal must necessarily give three indications. Whether this is so or not depends entirely upon the arrangement of the signals, their distances apart, &c.

Arrangement of Successive Three-position Signals.—The simplest arrangement is that illustrated already in fig. 74, and reproduced

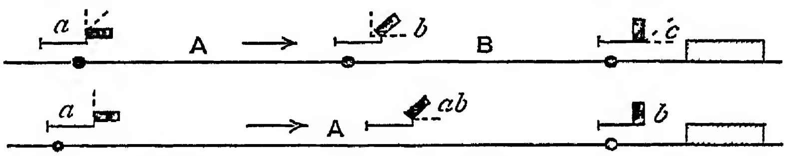


Fig. 75—Ordinary Three-position System and Modification for long Block Sections

in fig. 75. With upper-quadrant semaphores, signals *a*, *b*, and *c* are all three-position signals, governing sections A, B, C, and repeating the next signal ahead. This is satisfactory as long as the distances *ab*, *bc* are neither too long nor too short. If too long, delays will be caused by trains receiving the caution (45°) indication some time before it is really necessary, and it is better in the case of a long section to do as is shown in the second example and instal a separate signal *ab*, working from 45° to 90° only, to repeat *b* at a suitable distance and make *a* operate from 0° to 90° only, indicating for the section A. If, on the other hand, the sections are short the caution indication is too near to the stop signal and the driver is not warned early enough. This gives rise to a difficulty which is illustrated in fig. 76. As

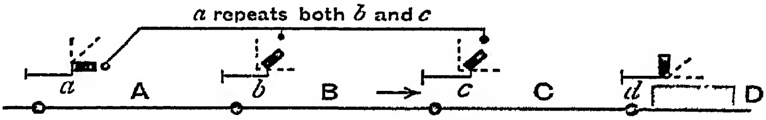


Fig. 76—Short Section Difficulty

the caution indication at *c* is too close to *d* it is repeated at *b*, and *a* does not show the 90° indication until both *b* and *c* are at least at 45°. Should a driver pass *a* in the position shown, on reaching *b* he has to decide whether to run on the indication before him or continue running on the indication of *a*. The indication at *b* means strictly " prepare to stop at next signal ", which is but a short distance ahead, and the driver would have to prepare to make an emergency stop, in order to be on the safe side, seeing that the necessity for such a stop may arise at any moment. If the driver is permitted to ignore the strict meaning of *b* because he found *a* at 90°, the whole value of *b* as a distant indication for *c*, should *c* be placed to danger in an emergency, is destroyed just when it is most wanted. For these reasons it has been necessary to consider giving additional signal indications in order that the driver may be in no doubt as to what he is to do.

Three-block Indication System.—This was first introduced on the Pennsylvania Railway, and is illustrated in fig. 77. Every signal has two arms and lights. The distances *ab*, *bc*, *cd* are not sufficient for a fast train to pull up in, the sections being very short, therefore the caution signal at *c* is announced by another warning signal at *b*, which signifies "reduce to medium speed", and enables it to be acted on without difficulty. The use of this indication enables the doubling of the caution indication already referred to to be avoided.

Three-position Signals at Interlockings.—Route signalling, as used in English practice, may be employed with three-position signals, and has been adopted both in Belgium and New South Wales. In the United States, however, where route signalling has never met with much favour, and is not seen in the completely developed form it has reached in Great Britain, a code of signals has been drawn up and was issued by the Railway Signal Association in 1913. It is based on the principle of indicating the speed permissible and not the route set up. The code is shown

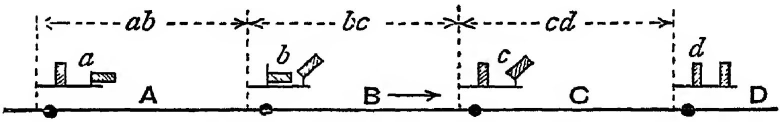


Fig. 77—Three-block Indication System

in fig. 78, and is divided into three schemes of varying degrees of complication. Scheme III has been adopted in South Australia and Victoria, with slight modifications. It will be observed that each indication conveys two facts, viz. (*a*) the maximum speed allowable for a given movement, (*b*) the condition of the next signal in advance.[1]

All the arms on any one signal are not always movable; some may be fixed, according to the particular application of the signal, and the low-speed arm is sometimes replaced by a colour light-signal or illuminated indicator.

Another code, combining the route-signalling principle with speed signalling in distant signals, is in use in Belgium.

Belgian Three-position Signal Code.—This is shown in fig. 79, and was worked out by the late Monsieur L. P. A. Weissenbruch. It is based on the use of the same types of signals as were employed in Belgium before the late War, and was introduced when the signalling of the State lines (largely remodelled on German principles during the occupation) was being reconstructed. Its distinguishing feature is the employment of both home and distant semaphores, each of which can operate, if required, to three positions. This means that a horizontal semaphore, by itself, does not always indicate "stop", but it results in great simplicity of working, which is particularly desirable when, as in Belgium, the signals

[1] This code has also been used to enable successive three-position signals to display indications governing two classes of traffic, such as express and suburban trains, where two braking distances are involved

RAILWAY SIGNAL ASSOCIATION CODES OF SIGNALS

For Three Schemes adopted by them in 1913

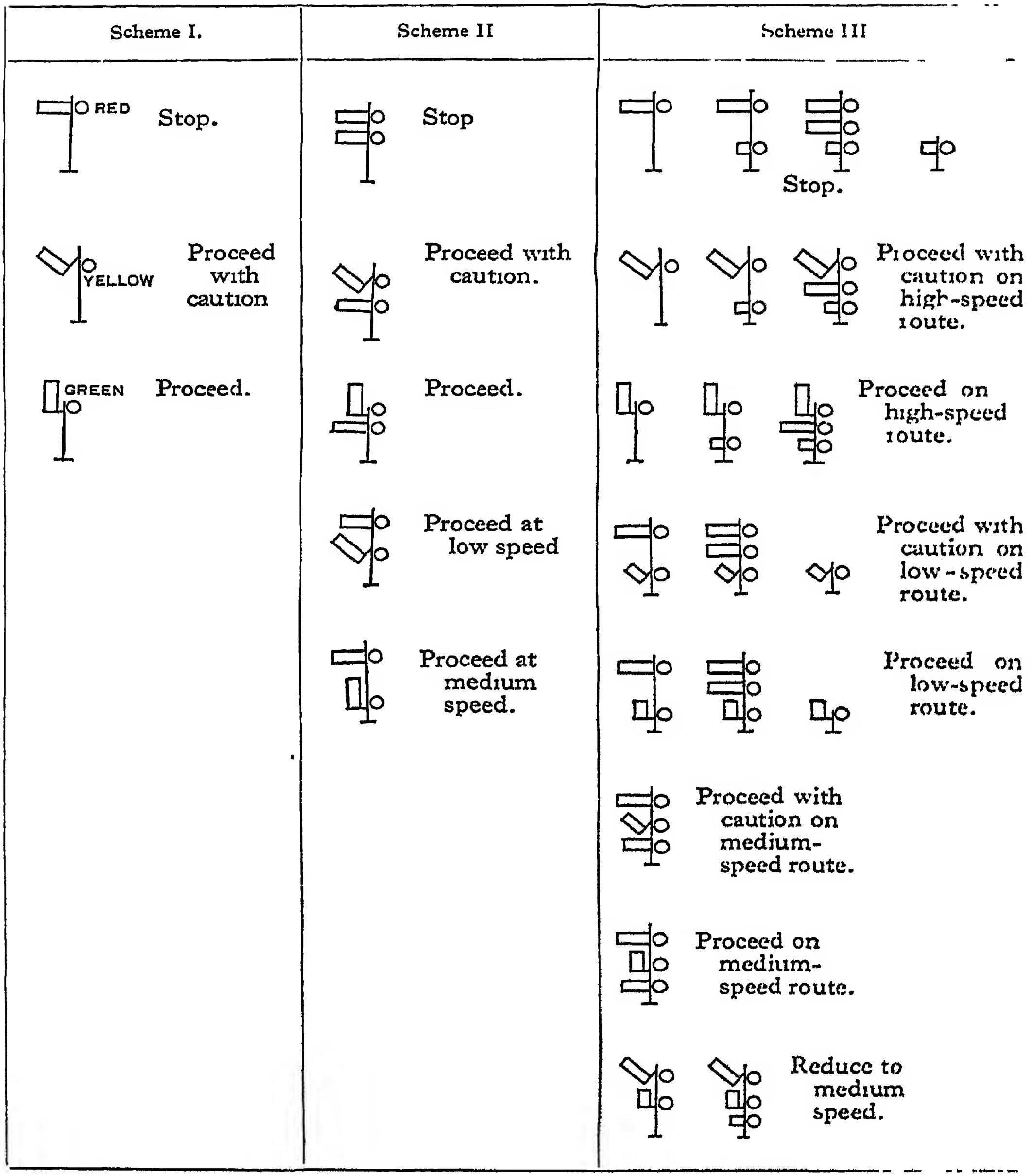


Fig. 78

are not operated by power, but mechanically, the various indications being in most cases controlled by slotting.

In this code there are four fundamental signs—and four night signals—one lantern being sufficient to give the whole of them. The stop semaphore can indicate "stop", "caution", or "proceed" (0°, 45°, 90°), exhibiting a red, a yellow, or a green light, as the case may be. The

" caution " indication signifies that the next signal ahead is at stop and is never used to convey any other instruction. The distant semaphore can indicate " caution ", " attention ", or " proceed ", the lights being yellow, green and yellow side by side, or green, in this instance. The " attention "

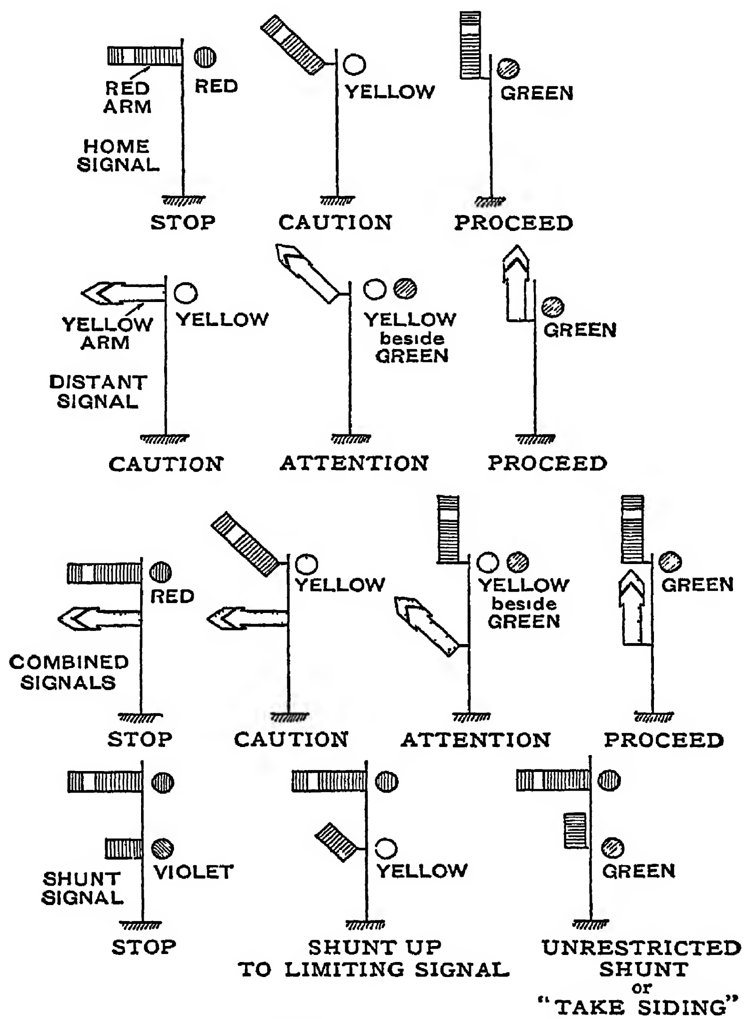


Fig. 79.—Weissenbruch's Belgian Signal Code

Junction signals are bracketed, as in England, and at terminals, &c , route indicators are used. Distant signals never have more than one arm.

Note The " proceed " signal authorizes the driver to run in the manner laid down in the general operating rules and special instructions for the section of track to which the signal applies.

signal is used when it is necessary to reduce speed so as to be able to act upon the restriction imposed by the next signal ahead, which may be a caution signal at less than normal distance from the stop signal which it repeats, or a proceed signal for entering a terminus or passing over a diverging route at a junction (fig. 80). By means of this signal the ambiguity already referred to, which arises when two caution signals follow one another, is removed. It is important to notice the meaning given to

the proceed indication in this code. It instructs the driver to proceed in the manner authorized by the operating rules for the section of line governed by the signal showing the indication, and the driver is presumed to know

Fig 80—Three-position Distant Signal at Junction, Belgian State Railways

these rules and to be thoroughly acquainted with the road. For this reason a proceed indication is given by a home signal leading into a terminal road, contrary to American practice, which employs caution for this purpose, since it instructs the driver to run in the manner laid down for entering

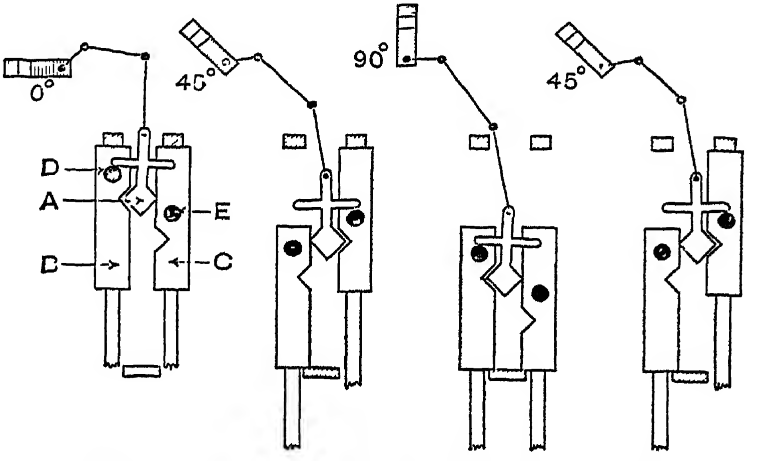


Fig. 81.—Action of César Rotary Slot (Three-position Signal)

termini. Thus the 45° and 90° indications of stop signals, in so far as they relate to signals ahead, only do so in respect of movable signals, the indications of which the driver cannot know beforehand, and not to permanent stop signals, such as buffer-stop lights which never change, and with regard to which the driver cannot therefore be in doubt.

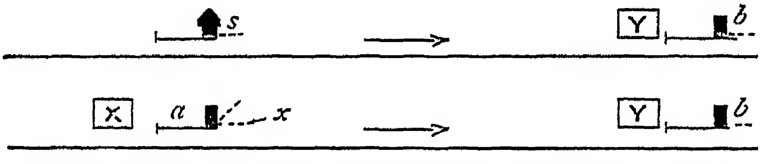


Fig. 82.—Simple Case of Three-position Signal, Belgian State Railways

By combining home and distant arms on one post a signal may be made to give all the four indications. The double-light, yellow and green side by side, is obtained by means of a reflecting lantern from one source of light, the reflecting portion being glazed green while the other portion is fitted with an ordinary clear lens. A spectacle moves in front of this, carrying coloured glasses, and the green light is masked when required by

sheet-iron extension pieces, or, in the case of the two-arm signal, by an independent sheet-iron mask moved by a rod attached to the distant arm. This code of signals has given great satisfaction since it was first brought into use in 1919 on the Brussels-Antwerp line.

Operation of Weissenbruch Signal System.—The chief engineering feature of the Belgian signalling is the employment of mechanical operation by double wires instead of power operation, which had usually been held

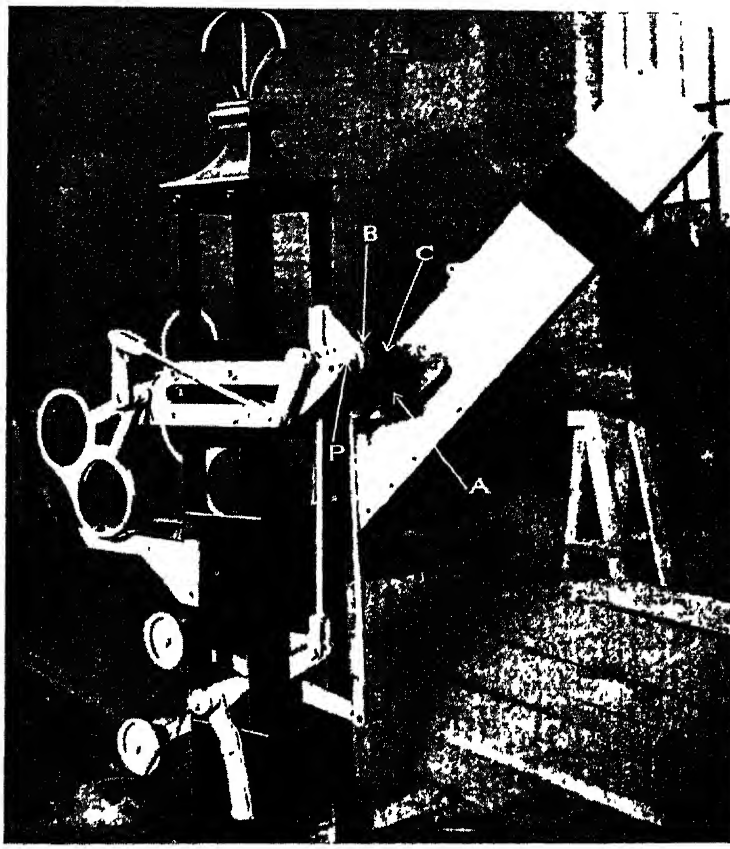


Fig. 83.—César Rotary Slot direct on Signal Arm Spindle

indispensable for three-position signals owing to the absolute necessity of always moving the signal arms to exact positions in order to avoid confusing drivers by doubtful signals. There is no difficulty in obtaining accurate working of the signals when double wires are used, as automatic compensation can be provided, if necessary. This is explained under the heading of double-wire working on p. 60.

It will be evident that since the 90° position of a stop signal is dependent on the pulling off of the next signal ahead, when that signal is near enough to require announcing by the 45° position of the previous signal, a slot of some kind must be used to obtain this result mechanically. There are two types of slot employed, the César rotary slot and the Charleroi slot. The

former is due to Monsieur V. César, Messrs. Railways & Signalisation, Brussels, and the latter to the Electric Construction Company of Charleroi

César Rotary Slot.—The principle of this appliance is shown diagrammatically in fig. 81, the movements being supposed to be in a direct line and not rotary, for the purposes of explanation. The signal arm is connected to the swinger A, which can engage with the notches cut in slides B and C, when forced to do so by the studs D and E. The slides are

Fig. 84.—César Rotary Slot on Signal Arm Spindle, cover on

driven by the double-wire transmissions from the cabin or cabins concerned. The action is positive in *both* directions, thus resembling a double-acting push-off slot, but with the important difference that one transmission cannot affect the other adversely, as the operation of the slot does not consist in establishing a point of support for the transmission that is last operated, which is the case with most push-off slots and which causes their working to be so unsatisfactory. The simplest application of this slot is shown in fig. 82. As shown at the top the cabin Y would ordinarily have a distant signal *s* repeating the home signal *b*, but should another cabin X be not more than 1000 m. in the rear the distant signal is suppressed and the home signal *a*, of cabin X, becomes a three-position

signal, remaining at 45° when cabin X pulls off, and signal *b* is at danger. The lever which usually works the distant signal for cabin Y now controls the 90° slot on signal *a*, that is, in fig. 81 X operates slide B and Y operates slide C.

The slot fulfils the following programme: as long as X does not move his lever, Y cannot affect the signal *a* however he manipulates his lever. If X reverses his lever first the arm moves to 45°, and then to 90° when Y reverses his lever. If Y reverses his lever first the arm moves to 90° when X reverses his lever. X can restore the signal to danger at any time, and when the signal is at 90°, Y is always free to return it to 45°.

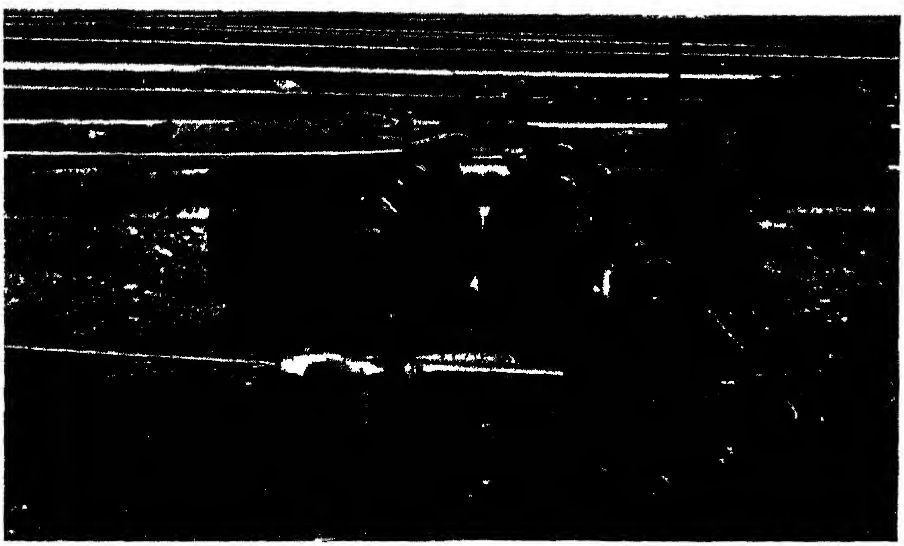


Fig. 85—César Rotary Slots in Run of Wires

Construction of César Rotary Slot.—This is shown in fig. 83. The blades in fig. 81 are actually discs B and C, with the swinger A engaging with them by means of rollers at each end. These discs revolve freely on the spindle P, to which the swinger is rigidly attached, and are operated by the balance levers on the signal post. The spindle P carries the semaphore arm, eliminating a special rod connection, the arrangement when in position occupying but a very small space, as may be seen in fig. 84. The case is filled with oil, effectually protecting all working parts. The same apparatus, having the discs set with the notches opposite to one another, may be used to control a two-position signal, and a modified form allows of the slot being fixed on the ground in the run of the wires (fig. 85).

Charleroi Three-position Signal Slot.—This is fixed lower down on the signal post and is connected by rod to the semaphore. It consists of two sets of cams acting upon a swinging-piece, the latter being attached

to the shaft of the crank which drives the semaphore, the cams being operated by the two balance levers (fig. 86). It enables the same working to be obtained as the César slot, but is less universal in its application. Both slots have overstroke on each move, both give exact signal-arm angles, and both lock the semaphore in all three positions.

Combining Slots for Complicated Cases.—To realize all the controls required in a large signal lay-out it is sometimes necessary to employ

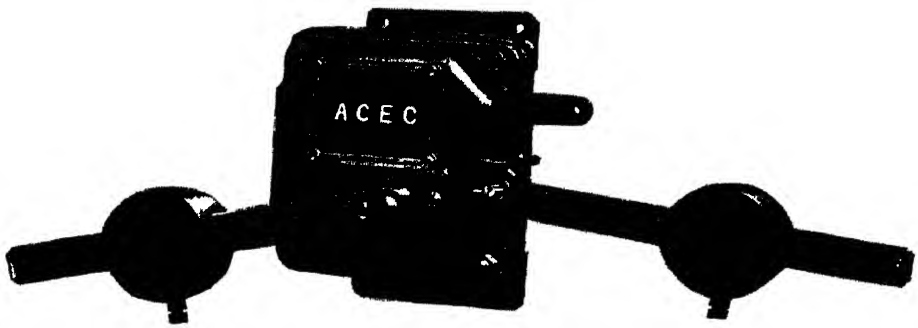


Fig. 86.—Charleroi Three-position Signal Slot

slots in combination and to supplement them by electric disengagers. To avoid unnecessary duplication of wires, distant signals placed under stop signals are frequently operated by a lever in the near cabin, which is freed when the required conditions obtain at the other cabin, a disengager being used to give continuous control and enable the cabin in advance to replace the distant arm independently. In certain cases, as with shunting signals, the three indications are obtained without any slot being employed, either by two transmissions, or by one transmission and a three-position lever.[1]

CHAPTER VI

Double-wire Signal and Point Working

In some Continental countries, notably in Germany where much thought has been bestowed upon it, the double-wire system of operating signals and, to a very large extent, points is employed.[2] It is now beginning to attract some attention in England and may eventually be introduced there.

There are two principal ideas which form the basis of the double-wire system. The first is to give a positive return movement to the signals so

[1] For a complete explanation of modern Belgian signalling see *La nouvelle signalisation des chemins de fer de l'Etat belge*, by J. Verdeyen and R. Minet. (Brussels, 1923. M. Weissenbruch Cie, 49 rue du Poinçon). (Paris, G. Ficker, 6 rue de Savoie).

[2] Signals are frequently operated by double wires in the United States where rod-worked signals are also employed.

as to avoid the dangers due to their remaining in the clear position unnoticed after the signalman has replaced his lever, which is always possible with the single-wire system, where gravity alone is relied on for the return effect. The second is to reduce the inertia of the whole transmission by making it work in a balanced state, and, by employing weights—not to assist the regular movements, but only to control expansion, contraction, and wire breakages—to make the working easier and smoother, thus reducing wear and tear. With the single-wire signal working, gravity is relied on every time a signal is put to stop, but in the double-wire system gravity only comes in in the rare event of a wire breaking. The disadvantages of the single-wire system may be seen by referring to fig. 87. The lever A operates the signal arm E through wire B and balance lever C, the weight on which (D) has to be heavy enough to pull back the wire under unfavourable circumstances. This weight has to be increased the further the signal is away from the cabin, and to assist the signalman it is necessary to put a back weight on the lever at F, which is very dangerous, as if the wire breaks at the moment of pulling the lever the signalman is thrown backwards with great violence and may injure himself. The wire is very likely to break in these circumstances, as the slack being suddenly taken up the inertia of the weight D puts a great strain on it all at once. As weights F and D are set off against each other and thus have to be made heavier and heavier with every increase in the distance between the signal and the cabin, the inertia of the system is at times very considerable and makes the working most erratic and unsatisfactory. The principles involved are mechanically unsound, because as the friction of the transmission increases, the weights F and D have to be increased out of all proportion and make it more and more difficult for the signalman to operate the lever smoothly and easily. There is also nothing to compel the signal to return to danger when the lever is replaced.

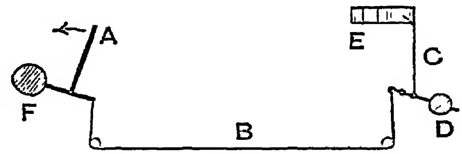


Fig. 87—Single-wire Working

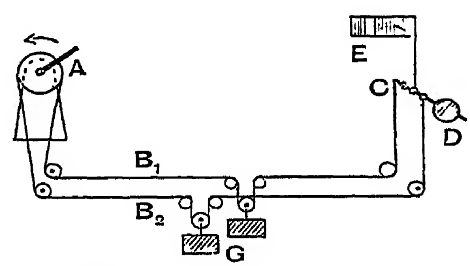


Fig. 88.—Double-wire Working

The double-wire system (fig. 88) is based on an entirely different principle. The signalman does not have any heavy weights to move, as the signal is pulled on and off, and is not returned to stop by gravity alone. Only a small balance-weight D is necessary on the signal post to assist in disengaging the signal altogether if the pulling-on wire breaks. The two wires B1 and B2 are kept constantly in tension by the compensation weights G, placed in the run of the wires, and these may be made very heavy as they do not have to be moved when the lever is pulled. The signalman

only has to overcome the friction of the transmission and the signal and thus the working is very much easier. It is customary to employ a smaller lever altogether, revolving a drum around which the wires are led and which enables a long stroke to be obtained with a constant mechanical advantage. No gain-stroke wheels are necessary for signals fixed at a distance such as are used with the English type of locking frame, and which reduce the mechanical advantage just when it is most required. Special precautions have to be taken in case of a breakage of the pulling-on wire (which otherwise would allow the compensator weight in the pulling-off wire to put the signal to proceed), and to prevent the signalman from forcing the compensator.

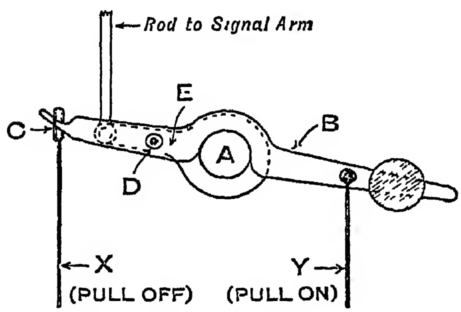


Fig. 89.—Disengaging Balance Lever

Disengaging Balance Lever.—Instead of an ordinary balance lever, a special one is employed which causes the signal to become totally disconnected if the wire which pulls it back to danger breaks. One form used on the Belgian State Railways is seen in fig. 89. The lever B rests on top of the spindle A, and the pulling-on wire Y is fixed to it at one end while at the other hooked end the pulling-off wire X is merely secured by the ring C. The gab-lever E, turning on the spindle, is connected to the

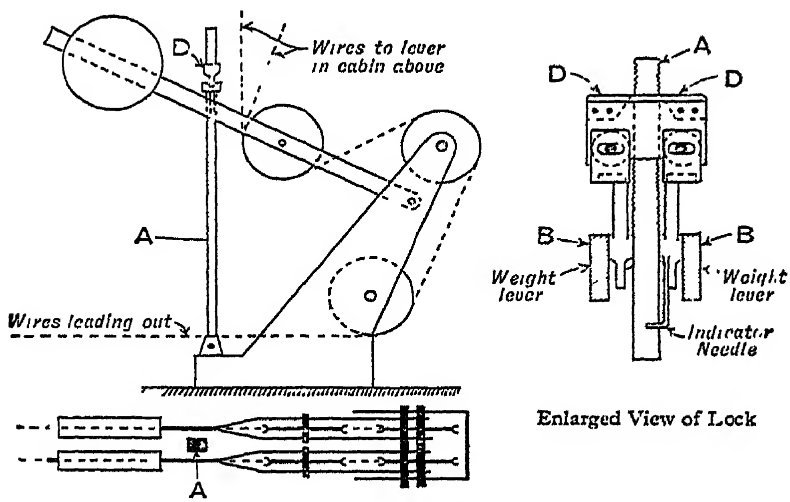


Fig. 90.—Compensator

signal arm, and a pin D passes through both E and B. Both X and Y being normally in tension, the lever turns in the same manner as an ordinary balance lever, but should Y break the tension on X tilts B round the pin D, allowing the ring C to slip off the hook, and the counterweight and signal arm (in this case an upper-quadrant arm) return to the danger position automatically. Another arrangement, fixed upon the arm itself,

the wires being led directly on to it, and due to Messrs. Siemens & Halske, is much used in Austria and Holland. It is based on very similar principles.

Compensator Lock.—There are various designs of compensator, but all consist essentially of an arrangement of weights and pulleys whereby the wires are kept in constant tension. Some forms have one weight only acting on the two wires, others a separate weight to each wire. Fig. 90 shows a compensator of the latter kind. It is necessary to prevent the signalman from forcing the lever over and raising the compensator weight idly while something is holding the signal wire fast, such as a detector in the transmission or some part of the signal itself jammed. This is accomplished by fixing a rack bar A between the two weight levers B, and connecting the latter by means of a link carrying toothed pieces D, which normally stand clear of the rack and do not hinder the rise and fall of the weight levers. When, however, the signalman operates his lever the tension in one wire is increased a little, while in the other wire it is correspondingly diminished, with the result that the link is tilted and a tooth thrown into engagement with the rack bar. This prevents any movement of the weight lever which is tending to rise, and allows the stroke on the wire to be transmitted correctly to the signal.[1] The usual tension created by these compensators is about 160 lb. Compensators are most frequently fixed under the signal box, but may be also fixed in the open.

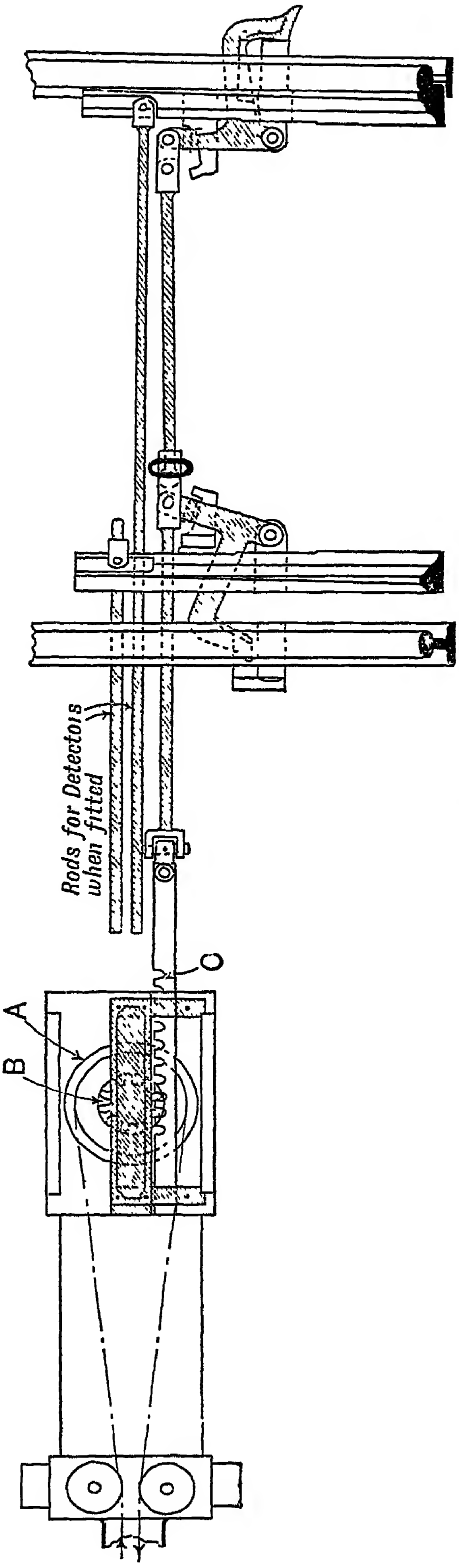


Fig. 91.—Prussian Point Mechanism for Wire Working

[1] Some compensators have a plain bar and friction-grip device instead of the rack bar and toothed link.

Double-wire Operation without Compensators.—It has been found that compensators can often be dispensed with, provided the transmission is given sufficient initial tension to begin with by means of the adjusting screws, about 200 lb. being a satisfactory figure. The changes in temperature cause the tension to vary, but do not sensibly affect the length of the transmission under these circumstances. The tension should be regulated about twice a year, being reduced a little when winter is approaching. The tension in the pulling-off wire discharges the disengaging balance lever when the other wire breaks.

Wires for Double-wire System.—Solid-drawn steel wire, about 4 mm. diameter having a breaking strain of 3500 lb., is used, and not a flexible wire, as in the English system, the latter being too elastic and variable as well as heavy. As this cannot be led round pulleys, it is necessary to use wire rope or chain at such points. Wire ropes need careful attention to detect deterioration, and are liable to stretch, but are lighter and freer moving than chain. In Belgium a light type of strong chain has been introduced which has proved extremely satisfactory. By using it the breakages in the transmissions (which used to occur with the wire ropes) have become almost unknown. Pulley wheels should be of large size, and those on the ordinary stakes should be from 2 to 3 in. diameter. This gives much easier working than the English type, which is far too small. It is now common to use ball- and roller-bearing wheels at right-angle turns in the double-wire system, which reduces the effort required by fully one-third. The easier working greatly prolongs the life of the fittings, as violent jerks and shocks are avoided.

Point Operation by Double Wires.—This is standard practice in some countries, such as Belgium, Holland, Prussia, Saxony, &c. There are many designs of point-operating mechanism, but space only permits of a brief description of one type, the principles underlying it, and its method of control. For this purpose the standard mechanism in use on the Prussian railways will be taken (fig. 91). It consists essentially of a wheel or drum A, with spur-wheel B on the same shaft, engaging with the rack C which forms part of the throw-rod of the points. The two wires are led round the drum and securely attached. The arrangement may be set parallel to the track or at right angles to it. The points are actuated through a special form of facing lock, the Büssing hook-lock, which operates in three stages and admits of the points being taken from the wrong direction without damage, a valuable feature in shunting-yards. This is shown diagrammatically in fig. 92. The switch tongues are not connected rigidly together, but each carries a hook A, supported in a stout bearing, the two hooks being coupled by rod C and joined to the operating drum by rod D, which is attached to the rack already mentioned. When the points are in one extreme position (say normal) one tongue is clamped to the stock-rail by the respective hook and the other tongue is held open by the operating rod, its hook resting against a sliding surface on the front of the hook-bearing. The movement from normal to reversed takes place as

follows: the operating rod first withdraws the hook which is holding the closed tongue, at the same time drawing the open tongue over. When the closed tongue is unlocked the two tongues move simultaneously, as both hooks slide against the faces of the bearings, until the other tongue is closed, when the remainder of the movement clamps it while opening the opposite tongue a little farther. A vehicle coming from a wrong direction first acts upon the open tongue and tends to close it, which withdraws the hook from the closed tongue in time, and throws it over before any damage can result. How this acts upon the lever in the cabin is explained later on.

Safety Lock.—As the point transmissions are usually fitted with

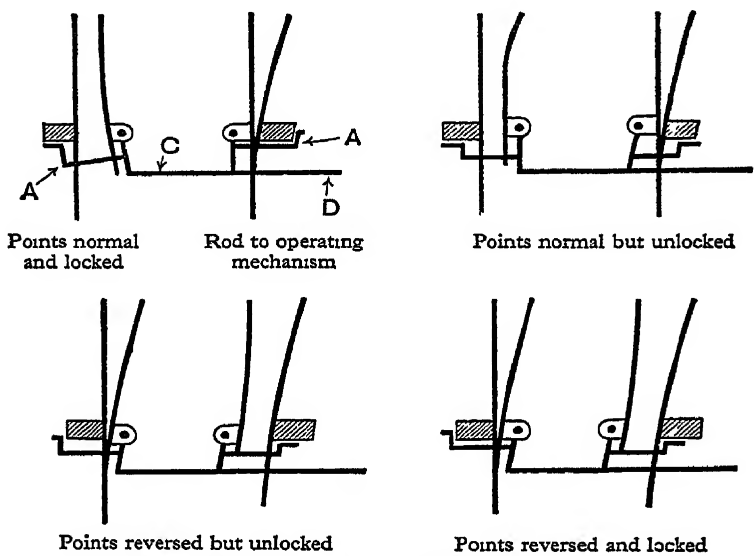


Fig. 92.—Diagram of Bussing Hook-lock

compensators it is very necessary to make sure that the points cannot be displaced should a wire break, and even when compensators are not used it is best to provide such a safety lock. This is accomplished by the catches E (fig. 93), which are fixed in the locking position by the wire itself as the drum revolves, in addition to being held under tension by springs. Should the wire which last operated the points break, the tension on the other wire cannot move them as the drum is stopped by the relative catch engaging with one of the projections F, which occurs before the hook on the closed tongue has moved far enough to unlock it.

Point Lever for Double-wire System.—This is constructed on similar general lines to the signal lever, with the exception that the handle is not rigidly attached to the drum, but engages with it through a spring-controlled coupling which is free to operate when the lever is in either extreme position (fig. 94). This coupling serves two purposes. It enables the drum to revolve independently of the handle when the points are trailed, that is run through from the wrong direction, through the force exerted

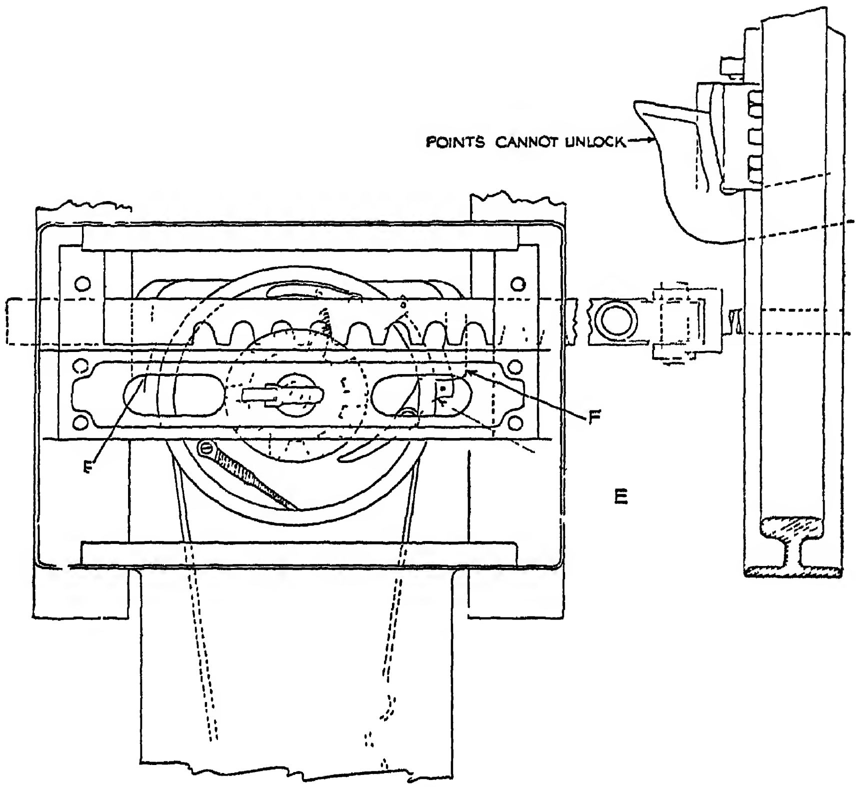


Fig. 93.—Diagram of Safety Lock

on the transmission. It enables the same movement to take place when a wire breaks, the compensator exerting sufficient pull on the other wire to overcome the friction coupling and revolve the drum. When the drum turns without the lever, an attachment at the side raises the catch-handle in mid-stroke and fouls the mechanical locking, which is always operated by the catch in this type of frame; at the same time a red "out of order" sign is brought out from behind the lever number-plate. The fouling of the mechanical locking prevents a signal being pulled off, leading over the points that have been trailed or of which a wire is broken. If a signal is already off, something must break if the points are trailed as the catch-handle is

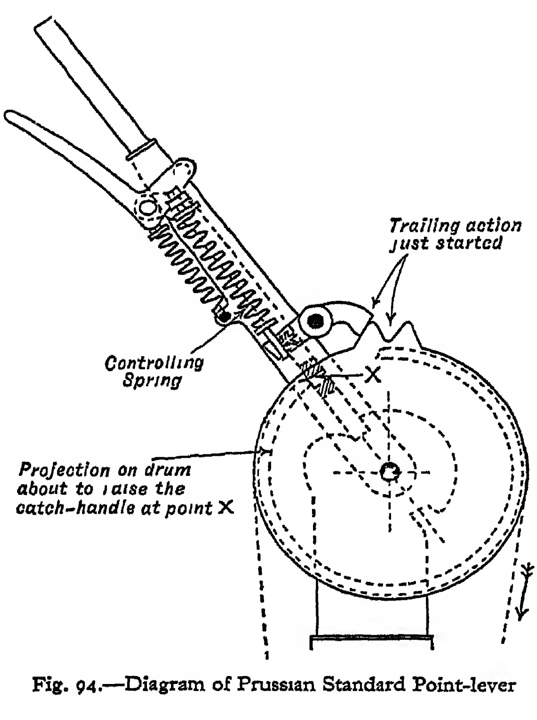


Fig. 94.—Diagram of Prussian Standard Point-lever

locked under these circumstances, but the liability of a run-through is rather remote after a signal has been cleared. However, one form of double-wire frame much used at one time in Belgium, designed by Siemens & Halske, permitted of trailing without damage even after the lowering of a signal, but this practice has not been generally followed. A special auxiliary handle which can be inserted in notches in the drum is kept in the cabin, and is used to rotate it back to its normal position after a run-through has occurred.

Detectors for Double-wire System.—When electric detectors are used these are of course of the same type as with the single-wire system, but mechanical detectors are constructed on a different plan. Instead of

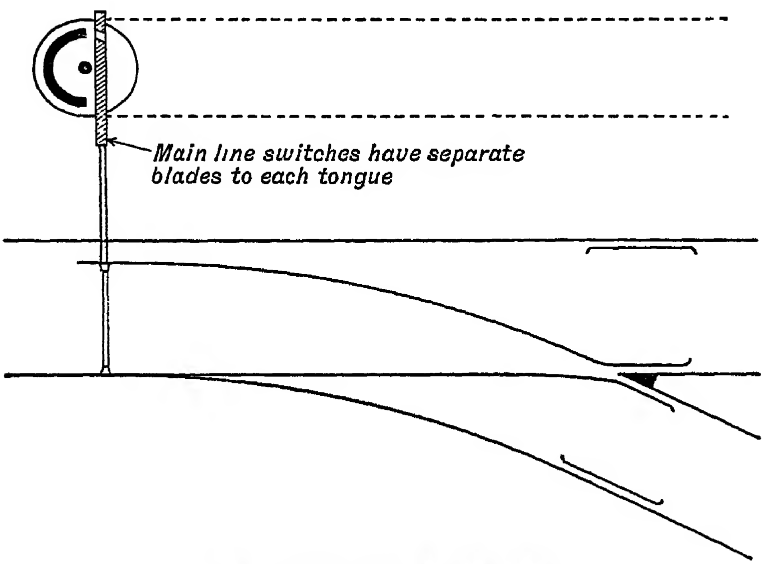


Fig. 95 —Simple Double-wire Detector

slides moving in a direct line, discs are used, revolved in the same manner as the drum which operates the point mechanism. These discs have ridges cast on them which engage with notches cut in slide-bars attached to the switch tongues, and thus detect and lock them in a similar manner to the single-wire detectors. There are two kinds of double-wire detector, the " ordinary " and the " intermediate ". The latter is employed when two or more have to be used in series in one wire transmission. The ordinary pattern (fig. 95) calls for no description here; it need only be remarked that it has to be constructed so that a wire breakage cannot cause a detector to free the tongues of the points at any time. The intermediate pattern has to fulfil the same requirement, and for this reason is equipped with gearing so designed that only equal movement of the two wires will actuate the detecting portion; this also prevents changes in temperature (which affect both wires equally) from moving the detector independently of the lever. There are different designs in use, but fig. 96 shows in outline the arrangement employed in the Stahmer intermediate

detector. The two discs A and B are included respectively in the two wires running from the lever to the further detector and are kept in tension by compensators. They are fitted with bevel wheels C and D engaging with the bevel pinion E, the spindle of which is fixed to the shaft F, which passes through the two discs and carries the detector plate G, the projections on the latter interlocking with the notches in the slides running to the switch tongues. Changes of temperature merely revolve the two discs in opposite directions without acting upon the shaft F, but regular movement of the lever revolves the whole arrangement and thus effects the detection. These detectors may be fitted in the transmission of signals as is done in the single-wire system, but are very often, especially at large stations, operated by independent levers, which much simplifies the working when signals have to detect several sets of points, necessitating in the single-wire system complicated runs of wires which cause the signals to work badly and are a constant source of trouble to keep adjusted. The detector levers act like the English F.P.L. lever, that is they interlock with the signals concerned, so that unless the points in a given route have been duly detected by these levers being pulled over a signal cannot be pulled off. It might happen that a wire became broken and the signalman pull over an idle detector lever, but this is prevented by the friction coupling, which frees the lever and the drum under the action of the compensators should this occur and keeps the mechanical locking held. A similar result follows any attempt to force the lever when the detector is foul owing to the points not having closed properly. Unless the detector levers are in order and correctly operated it is impossible to give a clear signal over the points to which they refer.

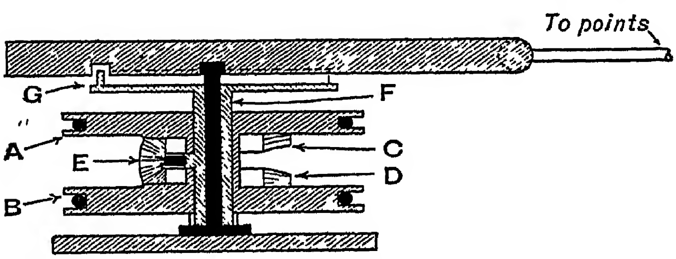


Fig. 96.—Diagram of Stahmer's Intermediate Detector

Operation of Signals by Cam Plates.—Instead of balance levers, cam plates are often employed to operate signals in the double-wire system, especially in Prussia. A wheel or drum at the base of the signal carries a cam plate having slots cut in it, or formed by means of raised ridges, in which a roller runs carried on one end of a crank or lever, which latter operates the signal arm by the usual down rod. The slot is arranged for a certain overrun at each end of the move, so that the exact stroke is imparted to the semaphore at all times, entirely eliminating doubtful signals. There are also no violent blows given by the fittings striking against fixed stops, which greatly prolongs their life. No disengaging arrangement is then used; instead of this the compensators revolve the drum around to a dead point in the event of a wire breakage, the cam slot being cut to allow this and to keep the signal at danger when it takes place. This method

of operation allows two conflicting signals to be worked on one transmission, that is by two wires instead of four. The cam plates have an idle move in one direction, and are set in opposite positions so that operating the transmission one way clears one signal and the other way the other signal. Two levers specially connected up are employed, fixed side by side in the lever frame.

Grouping of Levers in Double-wire Frames.—This does not need to be so carefully watched as with the single-wire type of frame, because the levers are clear of one another in their extreme positions. There is thus no difficulty in pulling over a lever between two already over, or in replacing a lever in the same circumstances. This allows greater freedom in arranging the levers in the frame.[1]

CHAPTER VII

Block Signalling (Non-automatic, Double-line)

There are two general methods of controlling the running of trains, viz. by time interval or by space interval. The former method was employed universally before the invention of the telegraph, and it is still in use in some countries to a limited extent, but it is so unsuited to the requirements of even a moderate amount of traffic that it has been superseded by the space-interval method, the general principle of which is usually called block working or the block system.

Block System.—The principle underlying this method of controlling the running of trains is that no train shall be allowed to proceed from a station or other clearly defined point unless a certain definite length of clear track is known to exist ahead, limited by a signal of some sort or a place where signals may be given, so that if the line still farther ahead is not clear, the train may be detained at such signalling point until it is. In this way a definite minimum space interval may be maintained between trains at all times. This may apply not only to following trains as on double lines, but also to opposing trains on single lines,[2] and to trains which can cross or foul one another's path at junctions, &c. The principle of the block system may be carried into effect by different kinds of apparatus, and these in turn may be non-automatic, semi-automatic, or entirely automatic in their action. In this way we have what is called the block telegraph, the lock-and-block, and the automatic block systems. These will be briefly considered in turn.

[1] It is impossible in the limits of this work to do more than briefly outline the double-wire system, which deserves careful study. Readers are referred to the many standard German works on the subject, almost all of which are to be seen in the Patent Office Library, Chancery Lane, London.

[2] See Chapter VIII.

Block Telegraph System.—In its original form this consisted in simply telegraphing the arrival and departure of trains from station to station by means of the ordinary telegraph instruments, and this is still done in some countries. The telephone is also used in the same manner, especially in the United States, but in Great Britain neither of these methods of block signalling is now permitted, independent telegraph instruments called block instruments, which give a continuous indication of the state of the line, being required. These instruments are not used for any other purpose than block working, it being forbidden to give any but the prescribed signals by means of them.

Block Instruments.—There are so many different kinds of block instruments that only a very few can be referred to here. They may be classed roughly into two sections—three-wire block instruments and one-wire block instruments, at least as far as British practice is concerned. In the former the up and down block signals and the bell signals are worked over separate circuits, necessitating three line wires between signal boxes, assuming that the earth is employed as a return conductor, while in the latter but one line wire and earth return are used. A further distinction lies in the fact that with one-wire instruments the various indications are given by momentary currents transmitted when bell signals are being given, whereas in the three-wire instruments two of the indications are given by a constant current, which is entirely independent of bell signals.

In the block telegraph system the signalmen communicate with each other by means of a bell code, something like the following:

Is line clear for express passenger train? 4 consecutively.
Train entering section, 2 consecutively.
Assistant engine in rear of train, 2 pause 2.
Train out of section, or obstruction removed, 2 pause 1.
Obstruction danger, 6 consecutively.
Has train reached signal box? 2 pause 3 pause 2.
Release tablet for shunting, 5 pause 2.
Shunting completed, tablet replaced, 2 pause 5.
Stop and examine train, 7 consecutively.
Caution signal, 4 pause 3.
Cancelling signal, 3 pause 5.
Last train signalled incorrectly described, 5 pause 3.
&c., &c.

Train Describers.—It is also necessary to arrange a code for describing the kinds of trains, i.e. whether passenger, slow goods, fast goods, engine and van, &c., and also their destinations. This is an easy matter when the number of different trains and destinations is small, but where it is large the number of beats required makes the exchange of block signals difficult. Much time is therefore saved by the use of a train describer as shown in fig. 97. The sending instrument is operated by means of clockwork, the needle being stopped in any position by inserting a peg

in the hole against the indication which it is required to send. As the needle passes over each indication a contact is made by which a current, after passing over the line wire, enters the receiving instrument and operates the needle a corresponding number of impulses by means of a pair of coils and an escapement gear similar to that used in a clock. Only one line wire is required for this instrument, and of course only one train can be described at a time.

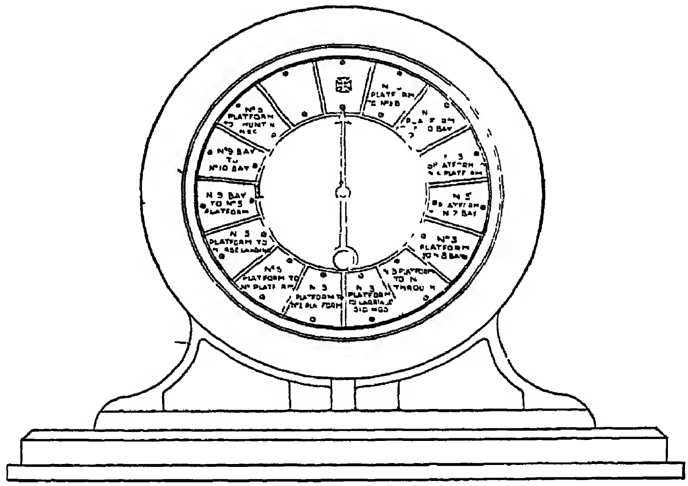


Fig 97.—Train Describer

It sometimes happens, however, that it is required to describe several trains at the same time; for instance, where there are several automatic sections between two signal boxes. In these cases a magazine describer is required. This requires four line wires, which gives a range of fifteen indications. The instrument, which is manufactured by the Westinghouse Brake and Saxby Signal Company, Ltd., is shown in fig. 98.

Messrs. W. R. Sykes Interlocking Signal Co., Ltd., also make a

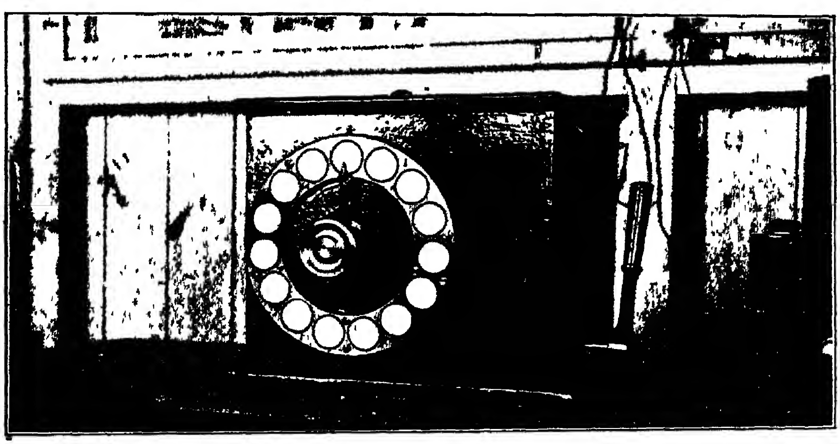


Fig. 98.—Westinghouse Magazine Train Describer

describer instrument, but it only requires one line wire, which is a great advantage. (See fig. 99.) It has no magazine feature.

Three-wire Needle Block Instruments.—The simplest form of three-wire instrument is the needle instrument shown in fig. 100, adapted from the original single-needle telegraph instrument. The handle can be fixed in its two inclined positions by a peg or other form of fastening, such

as a spring catch, to maintain the needle at " line clear ", or " train on line ". When no current is passing the needle points to " line blocked " or " line closed ". As a rule it is only the instrument at the leaving end of the section which is fitted with a handle, as it is the signalman at that end who controls the section, the companion instrument at the entering end having a dial only. Some companies, however, employ the needle for giving dial signals indicating the class and destination of the train, and equip the instrument at the entering end with a handle which has no means of being fixed in any one position, but is merely used to give beats on the needles to the right or left according to code.

Where this practice is not followed, the indicators for each direction are often combined in one case as shown in fig. 101, the upper needle referring to trains going and the lower needle to trains approaching, the handle for the latter being underneath. This economizes space, and is a valuable feature in busy signal boxes.

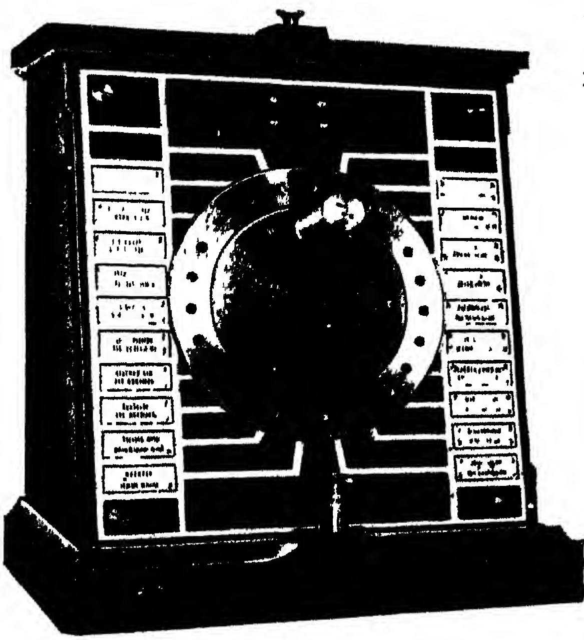


Fig. 99.—Sykes Train Describer

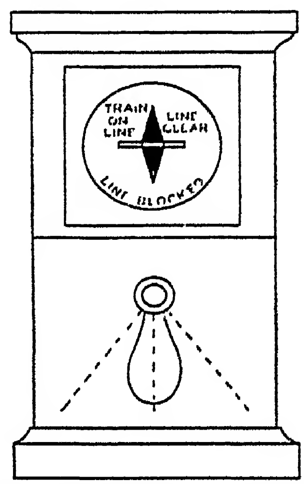


Fig. 100.—Three-position Needle Block Instrument

Three-wire Disc Block Instrument.—This is a modification of the needle instrument and is shown in fig. 102. The interior mechanism operates an indicating flag which shows through an opening in a screen, so that but one indication is fully visible at a time. The inscriptions read " line clear " or " train on line " and the " line closed " indication is given by the flag hanging centrally displaying half of each. This is sometimes termed the neutral indication. Instead of a handle tapper keys are used which can be fixed down, one at a time, by a sliding catch, and there are thus two instruments to each block section, that at the entering end being keyless and that at the leaving end fitted with keys. As with needle instruments the disc instrument can be made as a combined instrument, with key and keyless discs in one case as illustrated. As far as the signalman

is concerned there is really no difference between the disc and needle instruments, both giving three indications.

Preece Three-wire Instrument.—This is shown in fig. 103. It gives only two indications by means of a miniature semaphore, which refers to the block section ahead of the cabin where the instrument is placed. The semaphore is maintained in the clear position by a constant current and is controlled by a switch seen in the diagram, resembling a miniature signal lever. Above the semaphore is a disc indicator which is operated by a polarized movement in the bell circuit, and is arranged to repeat the position, *on* or *off*, of the semaphore on the instrument at the other end of the section. When the signalman operates the block switch in order to change the position of the semaphore at the next cabin, the bell signal received in acknowledgment actuates the disc indicator, as the polarity of the bell circuit is governed by a switch inside the instrument oper-

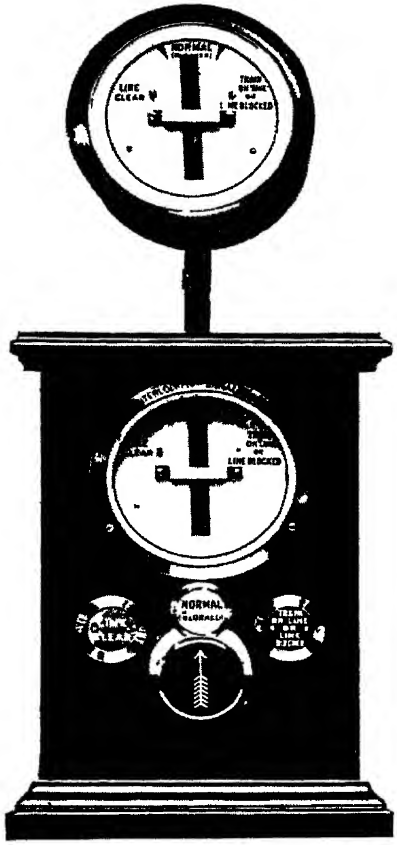


Fig 101 —Combined Three-position Needle Block Instrument

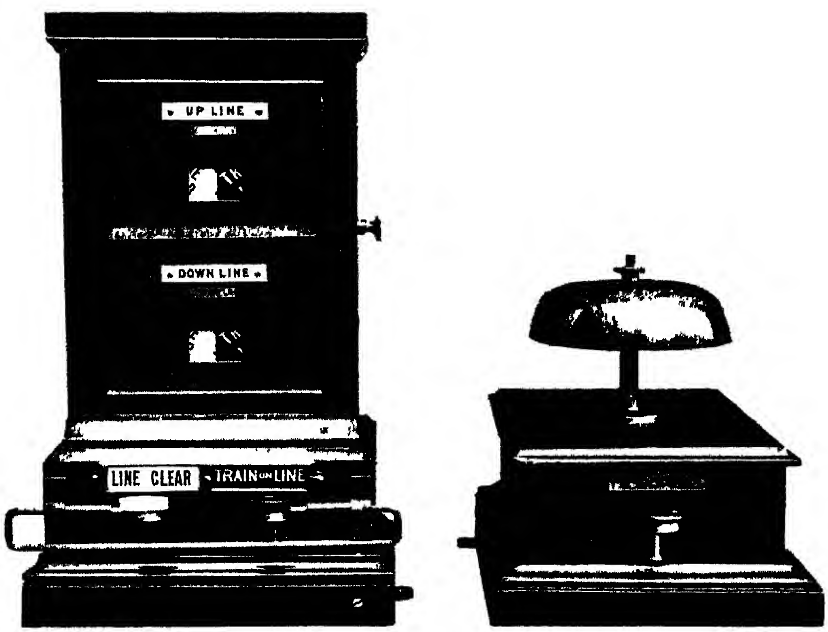


Fig. 102.—Standard Three-wire Disc Block Instrument and Block Bell, Great Western Railway

ated by the semaphore arm. In this way the signalman has a positive assurance that he really has operated the semaphore; this is a valuable safety feature of the Preece instrument. The bell mechanism is contained in the instrument case.

Three-position and Two-position Instruments.—Theoretically there are only two conditions of the line, viz. blocked or clear, since there must either be a train in a block section or the section must be unoccupied; but in practice it is found that something more than this needs to be considered in order to operate a block telegraph system in the most efficient manner.

Although a block section may actually be unoccupied it may yet be unsafe for a train to be allowed to pass through it and approach the signal-box ahead. For this reason in British practice a third condition of the line, called "closed" or "blocked", is recognized, and the line is regarded as being always in this condition unless a train is actually signalled. The "line clear" signal is given when the signalman gives definite permission for a train to approach him, and the "train on line" signal when the train is actually running in a block section. No train is allowed to proceed unless it has been offered to and accepted by the signalman in advance, in accordance with the bell signal code. The needle and disc instruments give three distinct indications to meet this method of working, as do all three-wire instruments except the Preece, but some types of one-wire block instruments give two indications. At first this was always so, but afterwards three-position one-wire instruments were designed and are in use. If the block instruments give two indications it is necessary to adopt one of two courses, viz. (*a*) maintain the indicators at "line clear" except when a train is in the section, or (*b*) maintain the indicators at "line blocked", except during the time that elapses between a train being accepted and entering the section.

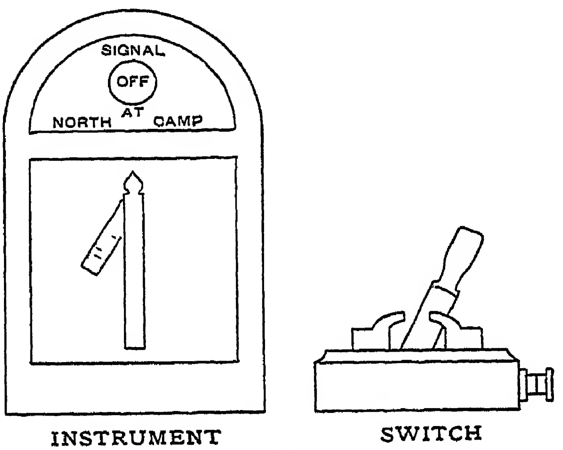


Fig. 103.—Preece Block Instrument

In the former case, the signalman can only tell whether a train has been accepted by observing a bell signal, which is very unsatisfactory. In the latter case he cannot distinguish between the normal condition of the instrument and the "train on line" condition, and must rely on memory or his train register book to know whether a train is in the section or not. This is also unsatisfactory, but practice appears to show that it is not so unsatisfactory as the difficulty arising when the indicators are maintained normally at "line clear". To overcome these disadvantages to some

extent additional mechanical indicators are sometimes provided, operated by the signalman in advance for his own information alone, and when the electrical indicators are maintained normally at " line blocked ", these arrangements are fairly satisfactory. Two-position block instruments have given very good service in spite of these theoretical drawbacks.

One-wire Block Instruments.—There are many of these in use, but the principal types are the Harper, Preece, Tyer, and Walker. An improved Sykes instrument has lately been introduced. All are operated by momentary currents transmitted when bell signals are given, the indicators remaining in position by magnetic induction until another signal is given intended to change them.

Walker's Instrument.—This is a very old instrument, designed by the late C. V. Walker, telegraph engineer to the old South-Eastern Railway, and prominent in the early days of train signalling. It is shown in fig. 104, and consists of a miniature signal post, with an arm for each direction, operated by polarized armatures, a bell mechanism, commutator, and ringing plunger. It was first used on the opening of the Charing Cross Railway in 1864, and remains practically unaltered to this day.

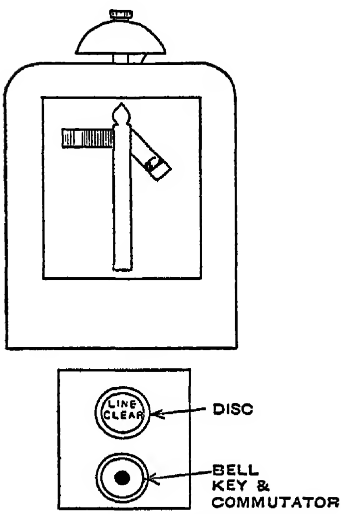


Fig. 104.—Walker's Block Instrument

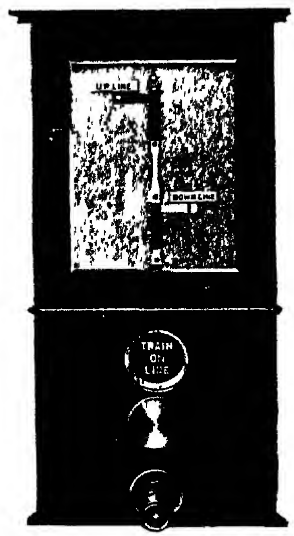


Fig. 105.—Harper's Block Instrument

Harper's Instrument.—Fig. 105 illustrates one pattern of this, which is extensively used. The mechanism is simple and works very satisfactorily, the current required being very small.

Preece's Instrument.—In appearance this is exactly like the three-wire instrument shown in fig. 103, but does not give the same safety feature described in connection with it. It is rather complicated, and has been superseded by the three-wire instrument a good deal in recent years. A peculiarity of it is that the semaphore is fitted with a lock which makes it necessary for both signalmen to co-operate in order to lower it to " line clear ".

Tyer's Instrument (Two-position).—One form of this is shown in fig. 106, and is provided with the additional indicator already referred to, in this case a disc with the necessary inscriptions painted on it, showing through an opening, and turning with the commutator. Another form of this instrument has no disc, but two plungers to control the indicators and

a separate ringing plunger. It is much employed. With these, as with all one-wire block instruments, any change in the indicators is accompanied by the ringing of the bell, which is permanently in circuit with the upper indicator, operated from the adjacent cabin. Instead of semaphores, Tyer's instruments are frequently equipped with needle indicators.

Tyer's Instrument (Three-position).—The latest type of this is shown in fig. 107, and in common with other one-wire instruments of this kind was designed to enable the disadvantages of the two-position instruments to be overcome while retaining the one-line-wire principle. It will be seen that the needle has three positions. The third indication, "line blocked", is produced by reducing the strength of the line current below that required for either "line clear" or "train on line". The commutator can be arranged so that after it has been turned to one position it cannot be again operated until the bell plunger is depressed. It can also be provided with a catch lock preventing the movements from taking place in anything but a definite order, the handle having always to be rotated in

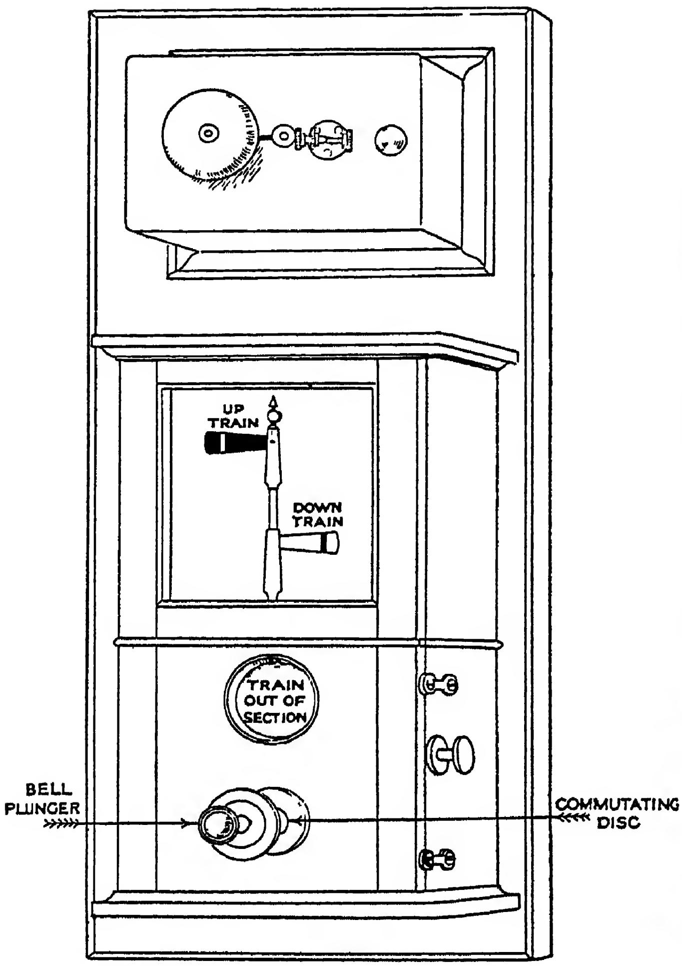


Fig. 106.—Tyer's No. 3 One-wire Block Instrument

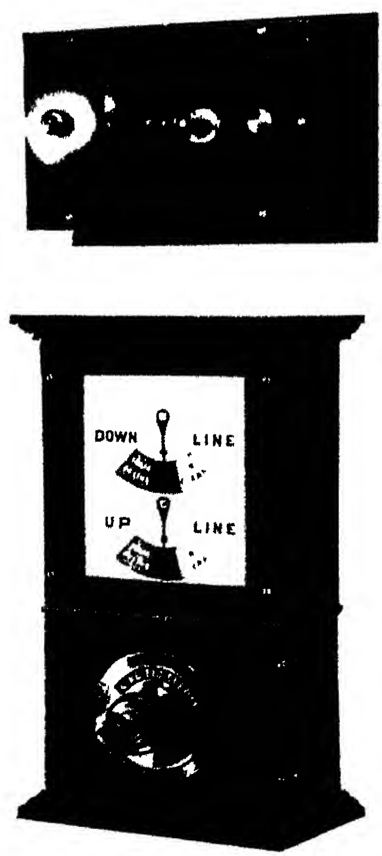


Fig. 107.—Tyer's "Simple" One-wire Three-indication Block Instrument

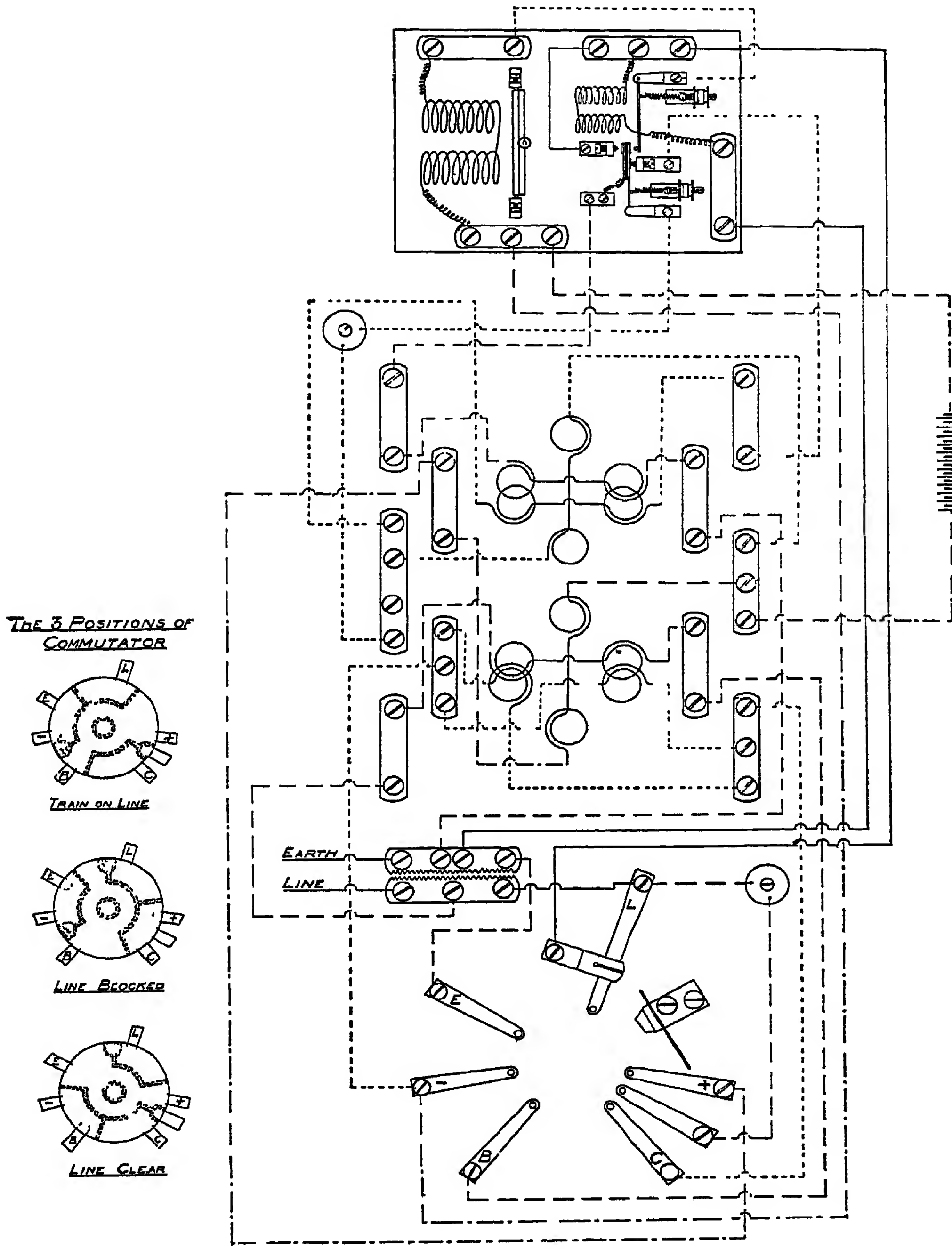


Fig. 108.—Tyer's "Simple" One-wire Three-position Block Instrument

a clockwise direction. Fig. 108 shows the electrical diagram for this instrument.

Sykes One-wire Instrument (Three-position).—This is seen in fig. 109. The general electrical principles employed are different from those used in Tyer's instrument, being derived from a one-wire three-position

instrument designed by R. R. Harper in 1885. The mechanism employed to give effect to them is, however, different, and is remarkable for its extreme simplicity. The needle indicators are bold and have a wide movement, making the risk of mistake extremely small. A difficulty experienced with one-wire three-position instruments is that it is possible to upset the indications of the needles by ringing at each end of the section at the same time, which is always liable to occur. In the Sykes instrument an alarm is sounded at each end of the section should both signalmen ring at the same moment, and thus they are able to communicate with one another to ascertain if correct signals have been transmitted.

Absolute and Permissive Block Working.—In absolute block working not more than one train is allowed in a block section at a time, except when assistance is required for a disabled train and has been asked for, but in certain places this working is too rigid, such as in goods lines and in large stations where trains are connected together, &c. In such cases permissive working is adopted, special block instruments having an indicator registering the number of trains in the section (as in fig. 110) being used. A train entering an occupied section is first brought to a stand and specially cautioned, either by hand signal, written instruction, or special fixed signal, that the line ahead is not clear. The use of this method of working is, in Great Britain, severely restricted by the Ministry of Transport to places where it is absolutely necessary, but in some countries, such as France, permissive block working is quite common. Special outdoor signals, having a numeral indicator working with them intended to

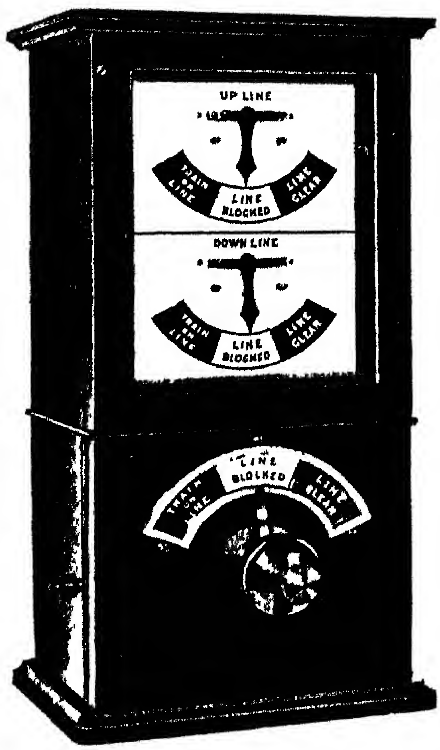


Fig. 109.—Sykes One-wire Three-position Block Instrument

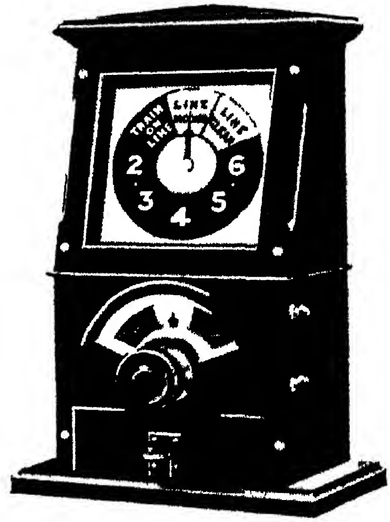


Fig. 110.—Tyer's Patent Permissive Indicating Block Instrument

denote to the driver the number of trains ahead of him in the section, are in use, but their value is very questionable, since it is impossible for the driver to know from them where the preceding train is likely to be met, since some trains may be very long, and others very short, and so on. The only safe way is to give the driver an unmistakable signal telling him that the line ahead is not clear, and requiring him to run in such a way that he can pull up within range of vision.

Warning Arrangement.—In the usual way, where absolute block working is in force, a signalman is not permitted to allow a train to approach unless there is an overrun of 440 yd. of clear line ahead of the home signal (to provide for errors of judgment, &c., which may cause the signal to be passed at stop to some extent), nor unless all points over which the train has to pass are in the proper position. This is found at times, especially where heavy, slow-moving goods trains are run, to unduly restrict the conduct of traffic, and therefore authority is given to the signalmen, at selected signal boxes, to accept a train when the line is clear to the home signal only. This is done by means of a special bell signal, "section clear, but station or junction blocked", and the signalman receiving this signal is required to stop the train and verbally caution the driver before allowing it to proceed, a green hand signal being exhibited at the same time. Some companies require in addition a printed cautionary order to be handed to the driver. As this is rather a clumsy method of procedure, and is open to several objections, some companies employ a special distinctive outdoor signal, which is pulled off when the train is accepted under the "warning" rule, generally on sections where lock-and-block is in use. Hand signalling with its risk of mistake is thereby eliminated.

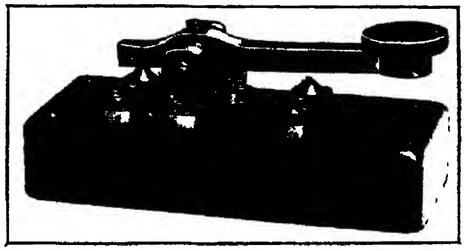


Fig 111 —Tapper Key

Bell Signal Apparatus.—Single-stroke bells and gongs are employed for giving the code signals necessary with the block telegraph, and are operated by means of a tapper key (fig. 111) or a plunger key (fig. 112), the former being often combined with the bell rung from the adjacent cabin (fig. 113). Care must be taken that, where more than one bell is fixed in a cabin, which is almost always the case, very distinctive tones are adopted for each to avoid risk of mistakes. Block bells may be operated directly on the line circuit or indirectly through relays in that circuit. In most cases the latter method is preferable, as the line current can be kept small and the full strength of a local battery can be employed to operate the bell when the relay is actuated. In this way powerful rings which cannot be mistaken are always produced although the conditions of the line circuit may vary considerably, due to weather affecting the insulation resistance, &c. At country stations where the signalman may also be employed about the station at certain times, extension bells, repeating the block signals,

may be placed in the booking-office or on the platform, and serve to prevent delays or accidents through a code signal passing unobserved. On the Continent, notably in France and Germany, large electric signal bells, giving a very loud ring, are often provided, and are rung from station to station as trains arrive and depart, being much appreciated by the public. There are no bells of this kind in Great Britain, however.

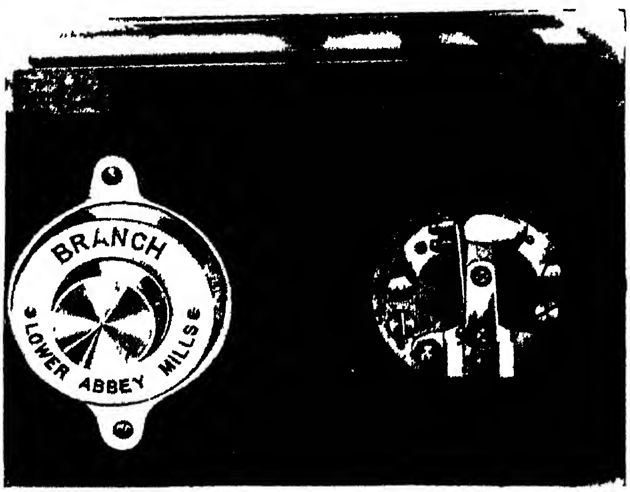


Fig. 112.—Bell Plunger

At suburban stations especially it is very convenient for the public and the station staff to know when a train is approaching, and for this purpose trembling bells, operated by the signalman, are often fixed on the platforms, being rung when a train passes the signal cabin in the rear. Mechanical gongs are also used for this purpose on some railways, worked by a lever in the signal cabin.

Lock-and-block System.—In the block telegraph system the security rests entirely upon the vigilance of the signalman. If he should give " line clear " when the line is not clear, or pull off a signal for a train to enter a block section when the block instruments show, for example, " train on line ", serious results may follow. Where special appliances are not provided there is nothing to prevent mistakes of this kind being made beyond the general rules under which the system is worked, which are always drawn up so as to make it difficult to commit an error. From time to time, in spite of the remarkably high degree of safety generally obtained, accidents of a serious kind have happened through momentary forgetfulness on the signalman's part. To overcome these defects in the block telegraph, what is known as lock-and-block is employed on some railways. This is an extension of the principle of interlocking, the block instruments and the signal and point levers being electrically and mechanically connected together so as to make it impossible for the mistakes mentioned to occur. For this reason the term interlocking block is preferred by some engineers when speaking of this method of signalling. In the United States it is known as controlled manual block.

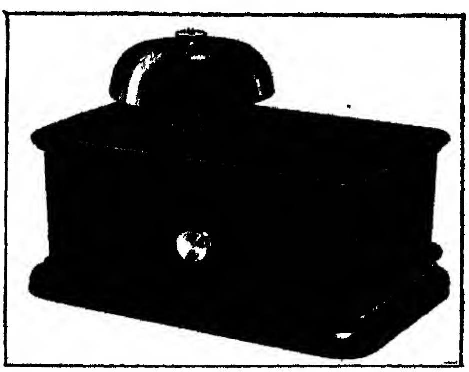


Fig. 113.—Tapper Key and Bell

The principal systems in use in Great Britain are the Sykes and the Rotary (or Midland) systems. Spagnoletti's system is also employed to some extent and was formerly much more used, having been originally installed on the London Metropolitan and some of the tube railways, where it has now been superseded by automatic signals. Sykes' system is in extensive use and has been developed to a high degree of perfection to cover junction working, &c., in a way not provided for in other systems. There are several Continental and American systems of lock-and-block, but space does not allow of their being described here. That of Siemens & Halske, Berlin, resembles the Sykes in the degree of development it has attained.

Fig. 114

Sykes Lock-and-block.—The block instruments are mechanically connected with the signal levers. Figs. 114 and 115 show the combined block instrument used at an ordinary block post, controlling rear and advance block sections. Contrary to the usual practice with block telegraph instruments, the Sykes instrument relates to the rear and advance sections for the same direction, there being thus an up and a down instrument in each box, for an ordinary double line. There are certain modifications between the Sykes instruments in use on the various lines, and therefore only one type will be described, as found on the Brighton and South-Eastern sections of the Southern Railway, and to which the figures refer.

Fig. 115

The electric semaphore over the instrument is normally at " clear ", and in this position indicates that the signalman in advance is in position to accept a train.[1] The upper opening in the dial normally shows " locked ", and relates to the lever of the signal for entering the block section ahead. The lower opening normally shows a plain white disc and relates to the block section in the rear. The indicating discs are carried on up and down rods, forming part of the interior mechanism, connected in turn to the rods below the instrument which communicate with the levers. The electrical locking mechanism consists essentially of a Hughes electromagnet, whose armature, constantly under spring pressure, is normally attracted, and supports by a roller and a catch the up-and-down locking rod which normally holds the lock in the signal lever, so that the signalman cannot pull it over. The release takes place when the signalman in advance presses the plunger of his instrument, the positive current so transmitted neutralizing the electromagnet and allowing its armature to be discharged by the spring, dropping the locking rod and lifting the lock on the lever. The sign " free " then appears at the upper opening in the dial. When the plunger is depressed, the lower indicator exhibits the sign " train on ", and a mechanical lock is brought into action which prevents the plunger from being depressed a second time until the signal lever has been pulled over and put back again. At the same time the negative current normally flowing in the line circuit is cut off, and in consequence the electric semaphore at the signal box in the rear assumes the " danger " position. When the signal lever that has been released is pulled over it actuates a cam which moves a roller attached to the bottom of the locking-rod, and raises it so that the armature of the Hughes electromagnet is restored to its original position and once more holds up the rod. The " train on " indicator is cleared and the plunger unlocked when the signal lever is replaced to restore the signal behind the train. To prevent this taking place before the train has actually passed into the block section ahead, the lever is locked when pulled over, and cannot be completely replaced [2] until the instrument has been released by a current transmitted by a treadle or rail-contact placed ahead of the signal. A switch, worked by a rod from the lever, at the back of the instrument in fig. 114, connects the block wire or the treadle wire to it, in the " normal " and " reversed " positions of the lever respectively.

It will be seen, therefore, that a signalman cannot pull off his signal unless it is released by the signalman in advance, who must pull off his own signal and replace it to danger after the train has operated the treadle before he can send another release, and so on. In this way mistakes which in the block telegraph might pass unnoticed and cause an accident cannot lead to anything, as the mechanism can only be worked in a certain definite manner.

[1] Or, more strictly, that he may be offered an " Is line clear?" signal. The semaphore can always be held at danger by the turning of the hook switch on to the plunger in the cabin in advance.

[2] It can be put back far enough to return the signal to danger again if necessary.

Sequence of Operations.—This is shown in the following table for the three block-posts A, B, and C illustrated in fig. 116.

Z ← D →

	A	B.	C
1	Signal locked. Instrument unplunged but ready.	Signal locked. Instrument unplunged but ready.	Signal locked. Instrument unplunged but ready.
2	Signal locked. Instrument plunged and locked.	Do.	Do.
3	Signal free. Instrument plunged and locked.	Signal locked. Instrument plunged and locked.	Do.
4	Signal lever pulled over and back-locked. Instrument plunged and locked.	Signal locked. Instrument plunged and locked.	Do.
5	Train passes and operates treadle. Back lock free. Instrument still locked.	Signal free. Instrument plunged and locked.	Signal locked. Instrument plunged and locked.
6	Signal replaced and lever locked. Instrument reset Unplunged but ready.	Signal lever pulled over and back-locked. Instrument plunged and locked.	Signal locked. Instrument plunged and locked.
7	Signal locked. Instrument unplunged but ready.	Train passes and operates treadle Back-lock free. Instrument still locked.	Signal free. Instrument plunged and locked.
8	Do.	Signal replaced and lever locked. Instrument reset. Unplunged but ready.	Signal lever pulled over and back-locked. Instrument plunged and locked.
9	Do.	Signal locked. Instrument unplunged but ready.	Train passes and operates treadle Back-lock free. Instrument still locked.
10, then same as 1	Do.	Do.	Signal replaced and lever locked. Instrument reset. Unplunged but ready.

NOTE.—Whenever an instrument is shown to be "unplunged but ready" the electric semaphore at the cabin in the rear is lowered. In all other cases it is raised

It will be seen from this table that the whole of the operations must take place in a predetermined order, and that the train as well as the signalmen enter into it.

Additional or Supplementary Section.—There are comparatively few simple block-posts like A, B, and C in fig. 116, and modifications in the system have to be made when additional signals protecting sidings, crossings, &c., are provided, as shown for example in fig. 117.

In this case the instrument locking signal *b* has no electric semaphore, but is otherwise like the usual double-line instrument, while an additional instrument is provided to lock signal *c*, with an electric semaphore but

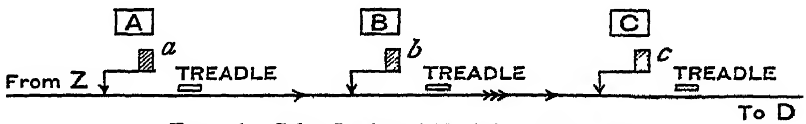


Fig. 116—Sykes Lock-and-block (see table, p. 83)

having no plunging mechanism and relative indicating opening in the dial. The locking mechanism of the *b* instrument is normally unlocked and is released, when lever *b* is normal, by the replacement to normal of lever *c*. Two treadles are provided for the back-locks of *b* and *c*. The lever for disc *x* is not locked at any time, but is nevertheless connected to the *b* instrument in such a way that when it is pulled over it locks that instrument; thus a train sent up to *c* from the siding automatically locks the protecting signal *b* until it has gone forward and operated the treadle ahead. Section BC thus forms a miniature block section under one signalman's control. When a train releases the back-lock of *b* and the lever is replaced, it resets the plunger mechanism, and another train may be accepted unless

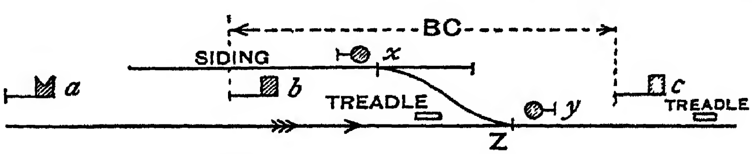


Fig. 117.—Supplementary Section

it is specially desired to prevent this. In that case the plunger is held until the *b* instrument has been unlocked by replacing lever *c*. This extra lock on the plunger is very often applied.

Points Interlocking.—The Sykes system is often interlocked with the point levers, which enables many valuable safeguards to be obtained. The interlocking is generally carried out mechanically. A handle is provided on the block shelf, which in one position locks the lever and frees the plunger of the relative instrument, the shifting of the handle reversing this locking. The handle cannot be moved, however, unless the instrument is unplunged and the point lever in the correct position. In fig. 117 points Z reversed would lock the plunger so that a train could not be accepted, while the act of plunging would hold points Z in position for the

train until the treadle for *b* is actuated and the signal replaced to danger. This idea is capable of almost indefinite extension, and may be applied to complicated junctions or to several conflicting block instruments at the same time. An electrical arrangement may be employed to accomplish

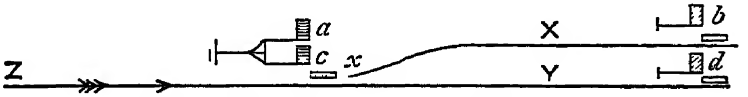


Fig. 118.—Junction Locking

the same thing. One of the chief features of the Sykes system is its adaptability.

Facing-points Interlocking.—The employment of the back lock enables route locking to be obtained very easily, as signal levers reading over facing points cannot be replaced until their treadle is operated, which effectually holds such points from being altered in front of a train. At some junctions an extra safeguard is in use where advance signals are provided, as illustrated in fig. 118. Two Sykes instruments control the signals *a* and *c*, and relate to the sections X and Y. If a train has been sent to stand at (say) signal *b*, signal *a* is locked. The plunger for the rear section from cabin Z cannot be used again unless points *x* are first set to lead to the vacant track Y, and when this is done their lever becomes locked and cannot be moved as long as X is occupied. Should the second train now be accepted the plunger is locked and cannot be used again till this train has gone through on the line Y, or, if it is held at *d*, until X is cleared and points *x* reversed. This locking can be extended to apply to any number of tracks.

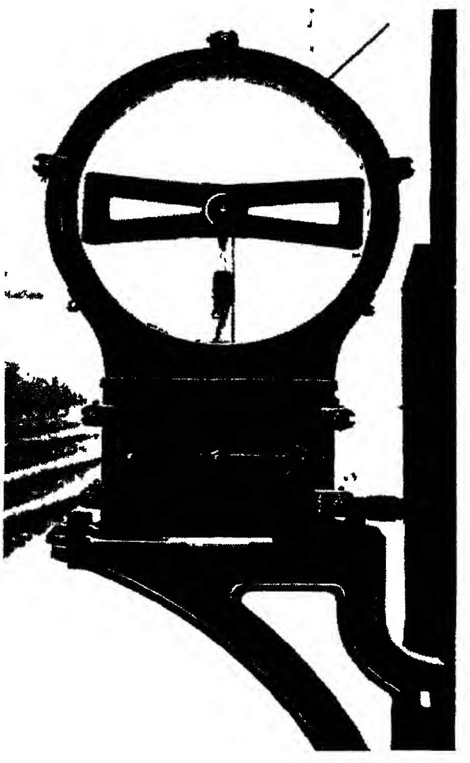


Fig. 119.—Warning Signal

Warning Arrangement with Sykes' System.—If the lock-and-block is installed so as to compel ordinary absolute block working to be observed, it is impossible to accept trains under the warning arrangement, since the signalman has no alternative but to work in accordance with the locking; nevertheless, by using special apparatus, the locking can be modified to allow of the warning arrangement being observed. In Sykes' system this is done by providing an additional signal of distinctive shape (fig. 119)

fixed under the section signal, as at *x* in fig. 120, which is locked by a special instrument working in conjunction with an extra plunger instrument at the cabin in advance. Thus, in fig. 120, should a train be standing between signals *b* and *c*, B cannot unlock signal *a*, but he can, by using the additional plunger, unlock *x*, which A can then pull off, authorizing the

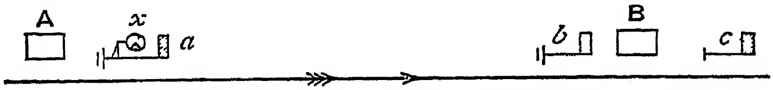


Fig. 120.—Warning Arrangement with Lock-and-block

driver to proceed under the warning rule. No hand signals are necessary as distinctive outdoor signals are always given, interlocked and controlled by the lock-and-block. The warning plunger is free at B directly a train is inside the home signal *b*, but the ordinary plunger is not free till the train has cleared *c* in the regular manner. The two plungers are mechanically interlocked. This interlocking has been much used on suburban lines to the south of London and has proved very useful and reliable. No extra line wires are required to work it.

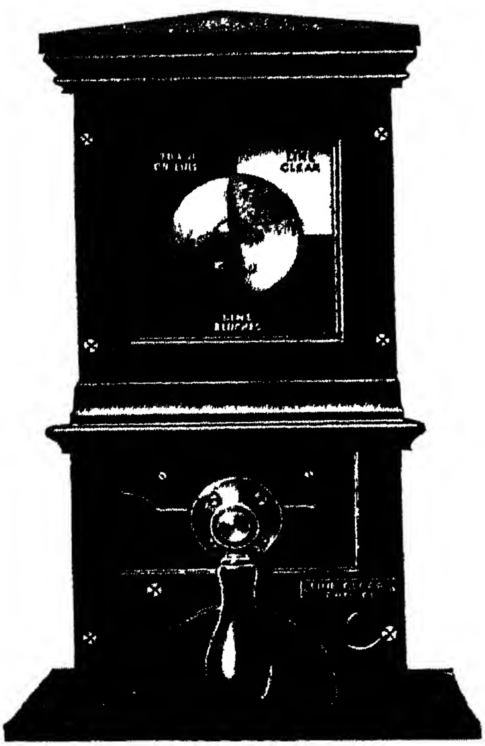


Fig. 121.—Rotary Block Instrument (Sending)

Other Features of Sykes' System.—Three line wires for a double-line block section are required, including the bell circuit, for the standard apparatus, but a modified form of the system requiring only two line wires is also in use in Great Britain, while on some Colonial lines a one-wire pattern is in use. Modifications to enable a three-position indicator to be used instead of an electric semaphore have been employed to some extent, while a "train accepted" as well as a "train on" sign is provided at some places. These details will not be described, as they do not affect the fundamental principles of the system.

Midland or Rotary System.—This is a development of a system due to the late W. E. Langdon, and is in extensive use on the Midland section, London Midland and Scottish Railway. It is entirely electrical, and only controls the section signal and the line between it and the home signal ahead. The block instruments are of the needle pattern (figs. 121 and 122), that at the entrance to the section having a dial signalling handle, while that at the other end of the section has a tapper for dial signals and

a rotary handle for block signalling which normally only moves in a clockwise direction. The electric lock on the lever catch-handle (fig. 123) is controlled by the current in the line circuit, and is unaffected by the small currents used to actuate the block needles. When the rotary handle is placed at " line clear ", however, it brings additional battery power into the circuit, and the current is increased sufficiently to operate the lock. Should the lever be replaced while this condition obtains, it is held by a mechanical catch which is not released until the electric lock once more

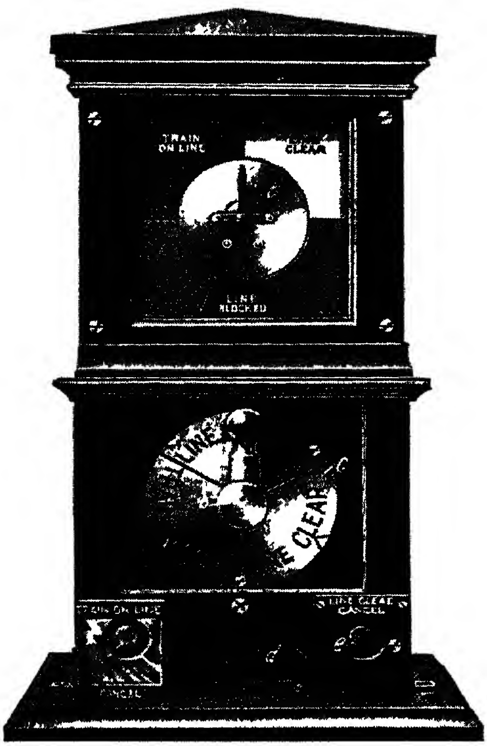


Fig 122 —Rotary Block Instrument (Accepting)

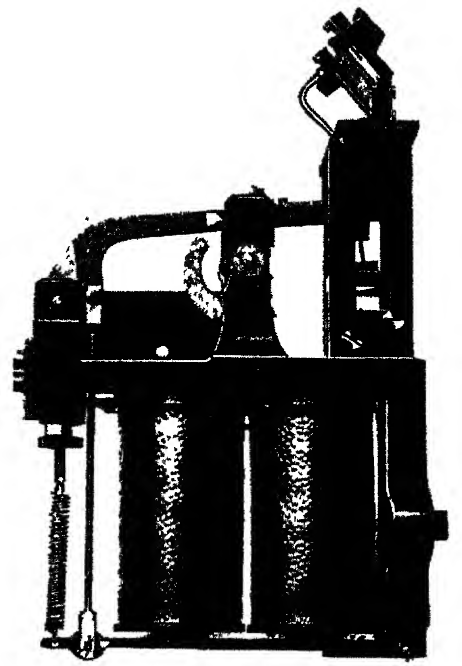


Fig. 123.—Lever Lock for Rotary System

drops into position; this in turn keeps the lever locked till " line clear " is again received. When the handle is turned to " train on line " it becomes locked until the train operates a treadle placed inside the home signal. It can then be returned to " line blocked ", but the home signal lever must be replaced before " line clear " can be given again. The line between the home and starting signals is track-circuited, and mechanical rotation locking between these signals is also provided. Four line wires to each block section are used.

Spagnoletti's System.—This is also an entirely electric system, the signal lever being controlled by an electric catch-handle lock. Separate line wires are employed for the block indications and for the lock releasing circuit, and the system is usually applied to the disc type instrument shown in fig. 102. The release of the rear signal lever is obtained by energizing

a stick-relay during the momentary depression of the " line clear " key, which does not in this case have to be pegged down, but sets a switch inside the instrument so as to maintain the block indicators at " line clear " when the key is released. The key is then automatically locked. The stick-relay drops when the signal lever is pulled and thus interrupts the lock-circuit until " line clear " is again signalled. The " line clear " key is unlocked by a treadle, just as is the handle in the rotary system. Supplementary section points and interlocking are also provided for.

Cancelling Apparatus.—In practice it is found impossible to adhere to the rigid sequence of movements imposed by the lock-and-block system when constructed on the lines already described. It may happen that a train requires to be cancelled and the block instrument reset, or that the train in passing over the treadle fails to unlock the instrument. In systems like the Sykes, which employ back locks on signal levers, a failure of the treadle may cause serious dislocation of traffic owing to the signal lever concerned holding points from being moved, &c., when in its over position. Some method of resetting the block instrument or releasing a back-locked lever must therefore be provided for use in an emergency. This may take various forms. In Sykes' system a key has generally been provided which the signalman inserts into the instrument or into a special contact box in order to release the apparatus. In Spagnoletti's system contacts placed inside glass- or paper-covered boxes are provided to prevent their being used without evidence of the fact. The Sykes key may be, of course, kept in a similar box. Accidents have happened through misuse of these arrangements, and to reduce the possibility of this, co-operative cancelling has been introduced whereby the signalmen at both ends of the section must act together in order to obtain a release. In Sykes' system this can be applied to any lock or instrument. In the rotary system it has been applied to the cancelling of the " line clear " signal, the buttons seen at the bottom of the instruments in figs. 121 and 122 being pressed in simultaneously by the signalmen concerned. The starting signal must be at danger before " line clear " can be cancelled. To cancel " train on line " the signalman in advance alone is concerned. He has to break a glass concealing a button, seen on the left in fig. 122, and press this to unlock his handle. Cancelling is more necessary when supplementary sections, junction interlocking, &c., exist, as in Sykes' system, than it is where plain block-section working alone is provided as in the rotary system, and for this reason it is becoming the practice to employ track circuits to protect movements within interlocking limits and restrict lock-and-block control to the ordinary block sections. When this is done it is possible to eliminate the dangers of cancelling altogether, and this has been done in the Sykes style " L " system, in its latest form.

Style " L " System.—This is entirely electrical like the rotary system, and employs an increment current to release the lock, but this is only transmitted at the moment of giving " line clear " and does not flow all the

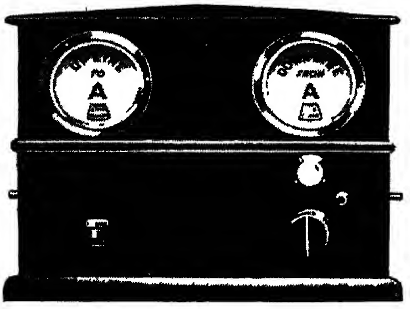


Fig 124 —Style "L" Instrument

time that indication is exhibited. The instrument is shown in fig. 124. The indicators are disc indicators, and a combined plunger-commutator is used. Up and down indicators and bell mechanism are combined in one case, and an alarm gong can also be provided which will ring automatically whenever the signalman omits to make the proper movements on the instrument or with his levers. The working is a little different from previous systems. The section signal, when released, does not become relocked by the mere pulling of the lever, but only if the train passes it or is cancelled. Cancelling can take place freely until but not after the train enters the section. After that it becomes impossible to interfere in any way with the apparatus. By this means misuse of the cancelling mechanism is avoided and the necessity for it reduced to a minimum. The instrument is, like the rotary instrument, unlocked directly by the treadle, but the home signal must be replaced in order to again give "line clear". Track circuit control is also provided for. Three line wires are required.

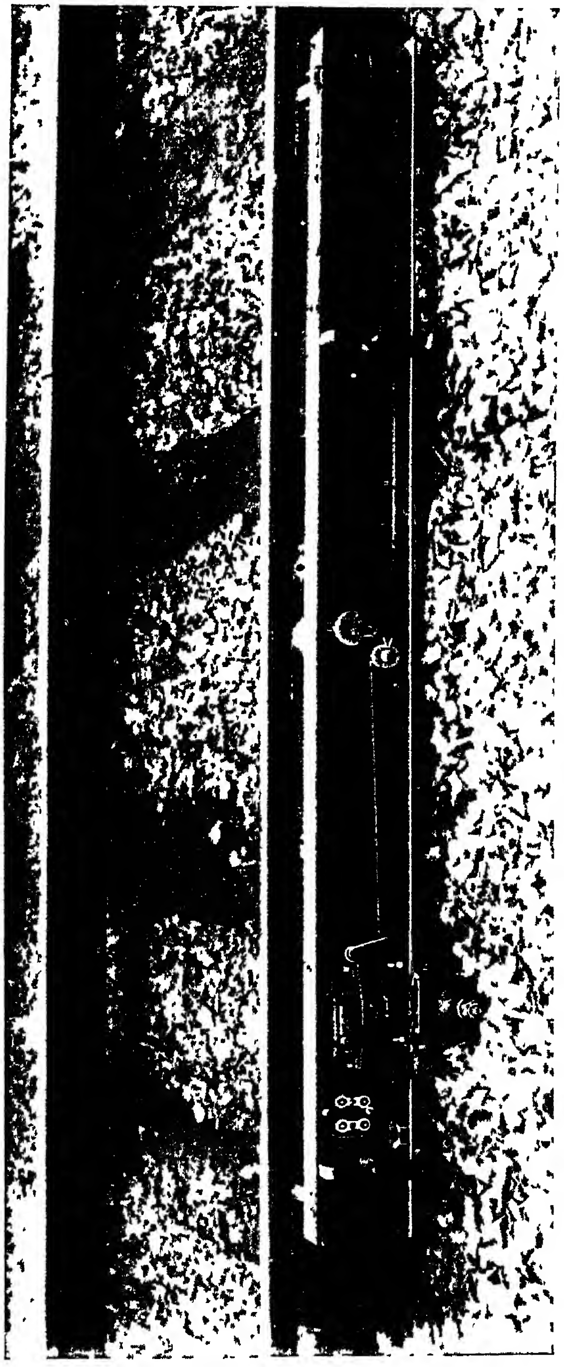


Fig. 125.—Sykes' Treadle

Electric Treadles or Rail-contacts.—These play an important part in lock-and-block. They are operated by the deflection of the rail as

a vehicle passes. There are many types in use. Sykes' treadle is illustrated in fig. 125. It is supported by cast-iron brackets at each end, bolted to the rail, a third bracket in the centre acting on the short end of a lever, the long end of which operates a mercury bath containing contacts.[1] Siemens' treadle is also carried on the rail (fig. 126), and has mercurial contacts, the deflection of the rail operating a hollow diaphragm D and forcing mercury into the contact chamber. This treadle is very sensitive, adapting it for use with the heaviest rails. Wood's treadle is shown in fig. 127. It is carried on the sleepers and is fitted with an electromagnet which holds the contact closed when once operated until the circuit is broken, which eliminates failures due to light engines passing very rapidly over the treadle.

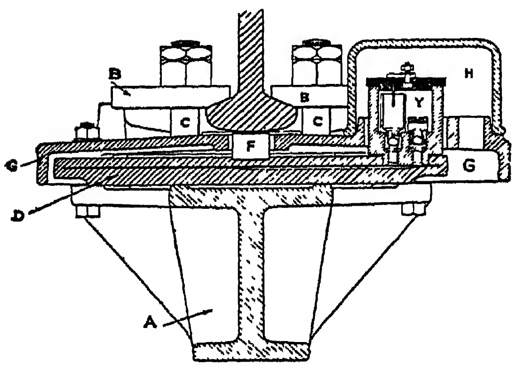


Fig. 126.—Section of Siemens' Mercury Treadle

Position of Treadle.—Where long trains are run it is necessary to fix the treadle at a maximum train's length beyond the exit to the section in order to prevent a release being given too soon. This leads to unnecessary delay when light engines or short trains are signalled. To overcome this an electric fouling bar[2] is often employed in conjunction with the treadle and fixed a few yards in the rear of it, the bar contact interrupting the treadle circuit as long as a train is on the bar. In this way the block instruments are not released until the tail of the train has

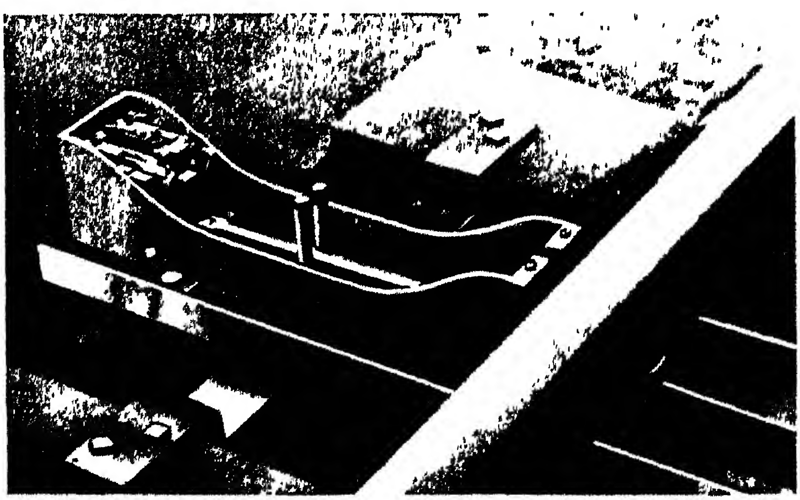


Fig. 127.—Wood's Treadle

[1] A spring contact instead of mercury can also be used.
[2] For description see Chap. XV.

cleared the bar, thus giving a constant releasing point for all trains in the correct position.

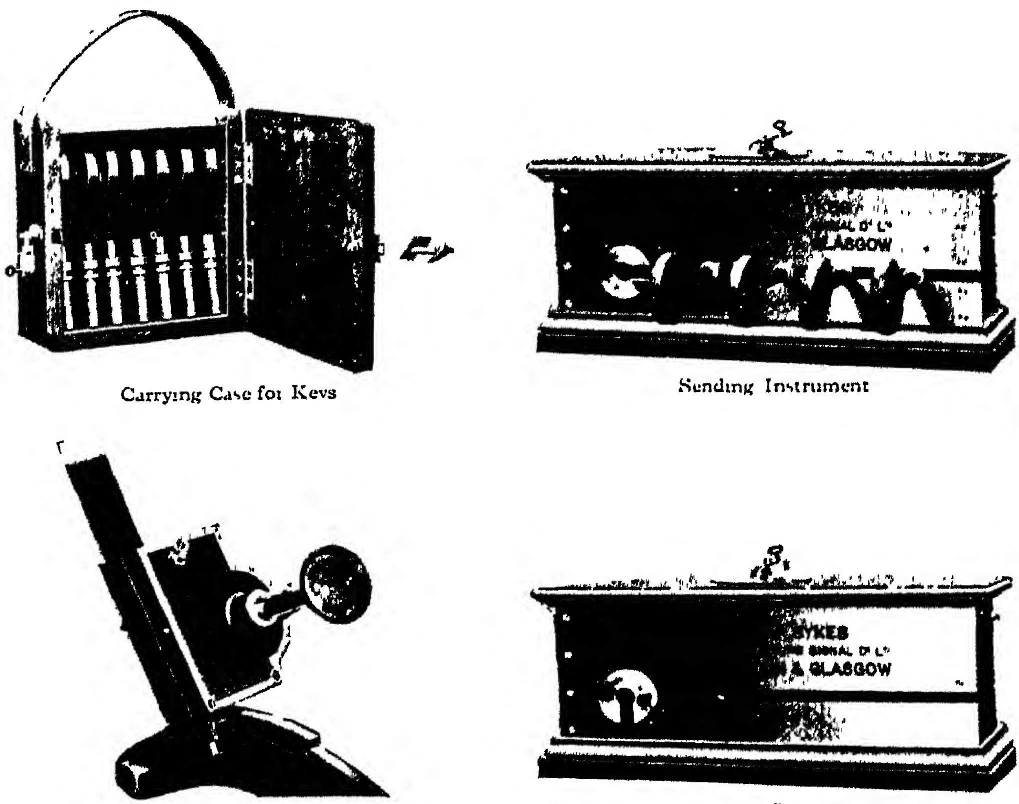
"Last-vehicle" Treadle.—A fouling bar alone, equipped with a special contact which transmits the releasing current as the bar returns to its normal position when passed over by a train, is used instead of a treadle and bar at many places, and on the Continent a treadle is often combined with a short length of insulated rail, so arranged that the action of the treadle is not finally completed until the rail is clear, giving the effect of a "last-vehicle" or "last-wheel" treadle, serving long and short trains equally.

Track-circuit Release.—The release of lock-and-block instruments by track circuit alone has sometimes been used, but it is not good practice, owing to the possibility of track-circuit failures giving a release at the wrong time.

Controlling Intermediate Sidings on Double Lines.—When a siding communicating with a running line exists in a block section it may be protected by a signal box with home and distant signals, the guard of the train being responsible for operating them and the points when a train requires to call there. The signals may be dispensed with if some means is provided of ensuring that the points are locked in position for the main line, and cannot be interfered with before a train can be signalled through the section. This in effect means interlocking the siding points with the signal for entering the section. Mechanical apparatus giving direct interlocking being out of the question, some indirect method must be employed. The simplest arrangement is Annett's key, which has been described on p. 12 in connection with ground frames. It has the disadvantage that the key must be brought back to the entering end of the section again, which is often very inconvenient.

Sykes' Intermediate Siding Key.—This is a development of Annett's key. The siding lever is controlled by the usual Annett's lock, shown in fig. 128, but there are several keys instead of one, contained in a special instrument seen on the right of the figure at the top. Only one key can be taken out at a time, and as soon as one is withdrawn it locks the signal for entering the section. The key may be replaced in the instrument (which unlocks the signal) or be taken through the section and placed in the companion instrument shown on the right of the figure at the bottom, electrically unlocking the other instrument and freeing the signal lever, which is fitted with an electric lock. Several sidings in one section can be controlled in the same manner. After a certain number of keys have been placed in the advance instrument, the stationmaster or lineman opens it and removes them, returning them to the other station in the special lock-up case shown at the top of the figure on the left, where they are inserted in the rear instrument, but through a special sliding cover so that the instrument is not unlocked by the returned keys, should a key be in regular use at the time. This apparatus can be used in conjunction with any block or lock-and-block system without additional line wires being required

Electrical Control without Keys.—Direct electrical interlocking between the signal at the entrance to the section and the points lever at the siding enables keys to be dispensed with, which is an advantage as there is nothing to get lost or damaged, but the apparatus is more elaborate. Sykes' system of control is in use on some parts of the Southern Railway. The lever at the siding is contained in a small hut to which it is impossible to obtain admission until the signalman at the entrance to the section locks his signal at danger and plunges on a special instrument unlocking one



Carrying Case for Keys

Sending Instrument

Lock on Lever

Receiving Instrument

Fig. 128

controlling the door of the hut and the lever inside. This enables the siding to be worked. When the train has to go forward the guard resets the points, closes the cabin door, and locks both it and the lever by raising the instrument handle, which is accessible from outside. He then presses a plunger, similarly arranged, releasing the cabin instrument. The signal is still, however, locked until the train has passed through the section, as the lock-and-block is provided as well as the siding control in most cases. This is not absolutely necessary, but without it the security is less than that given by the electrical key.

Interlocking of Block Instruments and Signals.—It is very necessary to guard against signals failing to assume the danger position when the lever is replaced in the cabin, especially distant signals. Although

signal repeaters are provided, signalmen sometimes fail to observe them and accidents have occurred through false clear signals being shown in this manner. Distant signals, being the farthest away from the cabin, are more liable to fail in this way than other signals, and as a false clear distant signal may easily lead to a train being unable to stop at the subsequent home or other signal, some companies employ an arrangement whereby " line clear " cannot be given to the cabin in the rear unless the distant signal is properly at danger. This control may be worked over the signal-repeater circuit, and this is the usual method, but the exact way of controlling the block instrument depends on the type of instrument in use at the cabin concerned. It must be impossible to give " line clear " unless the signal is at danger, but after " line clear " has been given the lowering of the signal must not affect the block indication. This safeguard may be usefully extended to stop signals, and employed also to prevent a stop signal from being pulled off unless the next one in advance is then at danger. It may be accomplished easily by equipping the signal arms concerned with contact-makers, similar to those employed for actuating signal repeaters, and the levers with electric locks. If the signalman must have his home signal at danger before he can accept a following train, and his starting signal at danger before he can pull off his home signal, and so on, the possibility of a stop signal hanging off and being wrongly accepted by a subsequent train is practically removed. The dangers due to signals hanging off may be eliminated by employing double wires and forcing them back to danger, instead of merely relying on gravity. This method of working, widely used on the Continent, is dealt with in Chapter VI.

Control of the block instrument in schemes of this kind may be positive, that is a lock may be applied to the handle or plunger manipulated by the signalman, or it may be negative, and simply cause the instrument to become dead and not respond when the usual movements of the handle or plunger are made. The latter method is not very satisfactory as it resembles a block-circuit failure, and may give rise to misunderstanding on the signalman's part under certain circumstances. This is particularly liable to occur if the signalman himself does not know that this control is in use—as may happen with a relief man—and it is a very good practice to have placed in each cabin a list (drawn up like a locking-sheet) explaining in a clear manner exactly what controls of this kind exist, so that a signalman who may be in doubt can refer to it easily. Some companies place locking-sheets in the cabins, and this also is an excellent practice and deserves to be more widely followed.

CHAPTER VIII

Single-line Working (Non-automatic)

The simplest method, theoretically, of operating a single line is to adhere strictly to time-table, and the precedence of trains with respect to one another which is shown in the time-table rules, but for obvious reasons it would be impossible to work a railway on such a rigid method in practice, without grave delays. At first in Great Britain, and to a large extent still in the United States, the time-table system was modified when occasion arose by means of orders issued by an official situated at a convenient point and having authority over a given section of line. These orders were communicated by telegraph, and later by telephone, to the stations where they were written out and issued to the train-men. The liability of mistakes being made with this method, which is called "train dispatching",[1] is very great, and many serious accidents have happened. It is not now permitted to be used in Great Britain.

Block Working.—The ordinary block telegraph is used abroad in many cases on single lines, but is not regarded as giving a sufficient degree of safety in England. Lock-and-block is widely used abroad, but is not permitted on passenger lines by the regulations of the Ministry of Transport, which require either the staff or staff and ticket or else the electric staff tablet or token systems.[2]

Pilotman.—An early method of control was to appoint a pilotman, distinguished by a special badge, who had to accompany every train or personally order it to start. This method survives on a few unimportant branch lines to-day in the pilot guard system. To avoid the employment of a pilotman the staff system was designed.

Staff System.—This consists in having a visible token or authority for travelling in each section in the form of a staff, made of wood or metal and suitably engraved, shaped, and coloured to distinguish it from one applying to an adjacent section. No train or engine must run in a section unless the corresponding staff is in the driver's possession. Assuming this rule is never broken, the security is absolute with this system of working, as there is but one staff for each section and no other signalling is really necessary, from the point of view of block working. There is, however, the serious disadvantage that trains must run alternately in opposite directions, or otherwise the staff may often be at the wrong end of the section.

Staff-and-ticket System.—To escape from the rigidity of the staff system, the staff-and-ticket system is used. In this case the staff is not the only authority to proceed through a section. The driver may proceed on receipt of a suitably worded ticket, signed by the issuing signalman, or

[1] This must not be confused with the dispatching on some European railways worked in conjunction with proper signalling.

[2] See Appendix, p. 249.

stationmaster, provided he sees that the staff is then at the station from which he is going. Thus the staff assumes the character of a direction regulator. Some form of block telegraph must be used in order to control a train following one which is carrying a ticket. Though much more flexible than the staff system, there is still a liability of the staff being at the wrong end of the section under certain circumstances.

Electric Staff and Tablet Systems.—These were introduced in order to make the token for the section available at either end at any time, if the line be clear. Several tokens are provided for each section contained in electrical instruments, the mechanism of which only permits of one being withdrawn at a time. A token can be replaced in the instrument from which it was taken or be carried through the section and inserted in the instrument at the other end, in each case restoring everything to normal.

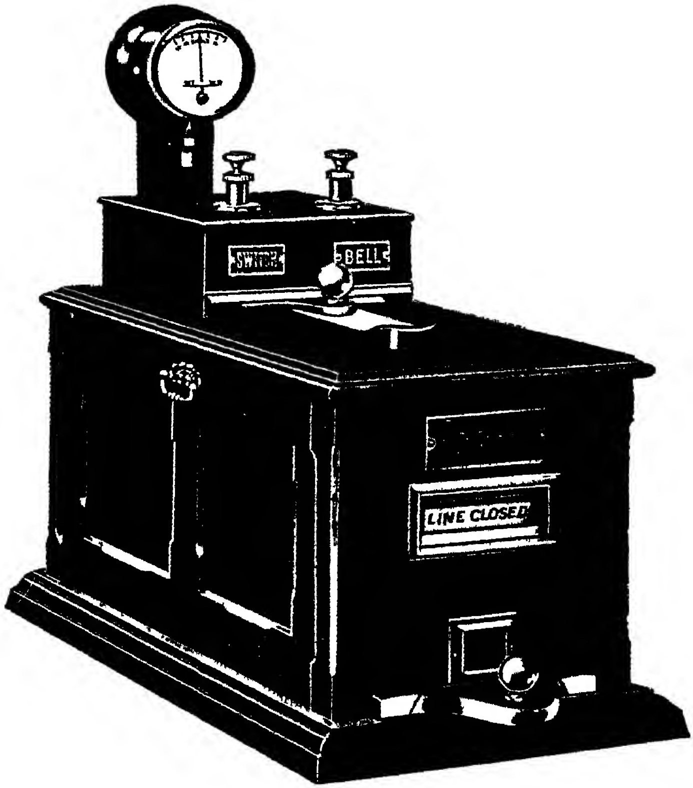


Fig 129—Tyer's No. 7 Tablet Instrument

Tyer's No. 7 Electric Tablet Instrument. — There are several patterns of tablet instrument, a modern type much in use being the No. 7 instrument shown in fig. 129. It consists of a galvanometer which indicates the passage of line currents; two plungers which are marked "bell" and "switch"; an upper slide which is used for restoring tablets to the instrument; a lower slide or drawer for issuing tablets; an indicator showing "line closed", "down (or up) train approaching", "up (or down) train on line"; and last, a small glass-covered opening through which the number of remaining tablets may be seen. The bell or gong is fixed in a convenient position above the instrument.

The method of working is as follows: A, who wishes to send a train to B, calls according to a prearranged code, and after receiving a reply holds down his bell plunger. At the same time B holds down his switch plunger and withdraws his lower drawer half-way, which reverses the commutator of the instrument and exhibits the indication "up train approaching";

he then holds down the bell plunger for a few seconds. Upon receipt of this signal, A holds down his switch plunger, which allows him to withdraw his lower slide to its full extent, and which automatically brings to view the signal " up train on line ". He now takes the tablet from the recess in the slide, and hands it to the driver, who carries it through the section and hands it to the signalman at B. The top slide is now pulled out, the tablet inserted in the recess, and afterwards restored. The effect of this is to unlock the lower slide, which is in turn pushed to its normal position, thus removing the indication " up train approaching " and substituting " line closed ". B now gives A the arrival signal and holds down on the last beat, thus enabling A to depress his switch plunger and restore his lower slide, which changes his indicator to " line closed ". Both instruments are now in their normal position.

When the running of a train is cancelled after a tablet has been obtained, the tablet is placed in the upper slide of the instrument from which it was taken, this operation permitting the tablet instruments to be restored to the normal condition.

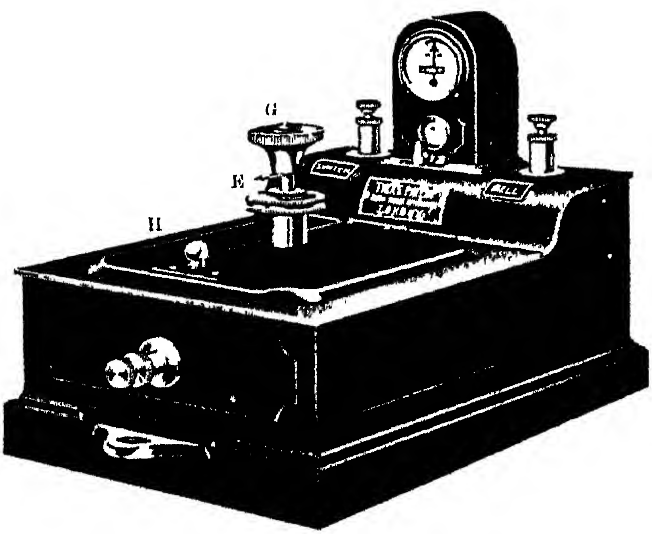


Fig. 130.—Tyer's Permissive Tablet Instrument

Tyer's Permissive Tablet Instrument.—On Colonial railways absolute block working is not always required, and it is very convenient to be able to send several trains in the same direction at the same time through a section. The original No. 5 Tyer's tablet instrument has been modified to meet this requirement, forming a permissive tablet instrument (fig. 130). It can be worked as an absolute tablet instrument, but when permissive working has to begin, the signalman at the B end of the section obtains a tablet in the usual way and inserts it in the drawer S, the effect of which is to enable him to re-set his instrument with the co-operation of A as many times as a tablet is required at A, for trains to run from A to B. The working cannot be reversed until the tablet in the drawer is restored to the B instrument, which cannot take place until as many tablets as have been taken out at A have been either replaced there or inserted in the instrument at B. The drawer only accommodates one tablet; the tablets are ordinarily carried in a rotary magazine which is revolved by the signalman turning the knobs G and E, according to circumstances, and they are taken out through an opening covered by the lid H.

Tablet Pouches.—Tablets, which are usually made of brass, but sometimes of compressed fibre, are given to the driver in a leather pouch, fig. 131, with a hoop for passing the arm through, and when permissive working is in use, it is usual to place the tablets in special pouches having (say) triangular hoops instead of round. In addition to the engraving, tablets for adjoining sections are distinguished by having holes in the centre of different shapes, square, round, triangular, &c. Care must be taken not to damage a tablet or it may be impossible to put it in the instrument.

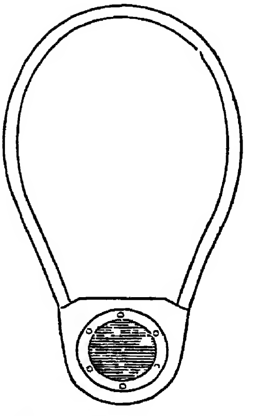


Fig. 131.—Tablet Pouch

Electric Staff Instrument.—The first form of this instrument is illustrated in fig. 132. The staffs are contained in a pillar surmounted by a case in which the electrical mechanism is fixed. This contains a series of drums under the control of an electric lock and controlling a commutator, the drums being rotated a quarter turn whenever a staff is taken out or replaced. Each quarter turn reverses the commutator, which controls the polarity of the outgoing current and the direction of current in the line coils of the electric lock, the local coils of which are energized from a local battery. The lock can only be lifted when the combined effect of the two coils produces a strong external magnetic field at one part, which cannot occur unless the instruments at both ends of the section have the same pole of the line battery connected to the line circuit. When a staff is required, the distant signalman gives permission by pressing his bell key.

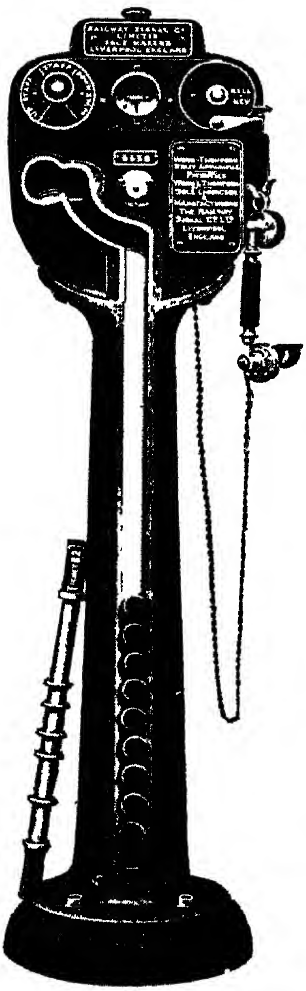


Fig. 132.—Electric Staff Instrument

The galvanometer is in the line circuit, and an interrupter switch is provided which enables the signalman to indicate that he has obtained a staff by causing the needles at both stations to return to the vertical position. A staff can always be placed in the pillar without communicating with the adjacent cabin. One line wire is sufficient, but sometimes it is convenient to provide a separate bell line and reserve the other entirely for controlling the issue of staffs. The instruments for each section are of course constructed so that the staffs referring to adjacent sections will not enter them. The most modern form of staff instrument is smaller than

the original type, and the staffs are much lighter and easier to handle. It can be operated by primary batteries or by a magneto generator, this being a great convenience in countries such as South America, Africa, &c., where the maintenance of primary batteries is very difficult to carry out efficiently. The local circuit previously mentioned is not employed, a permanent magnet being used instead. Telephones are frequently fitted to these instruments, and are operated over the staff circuit.

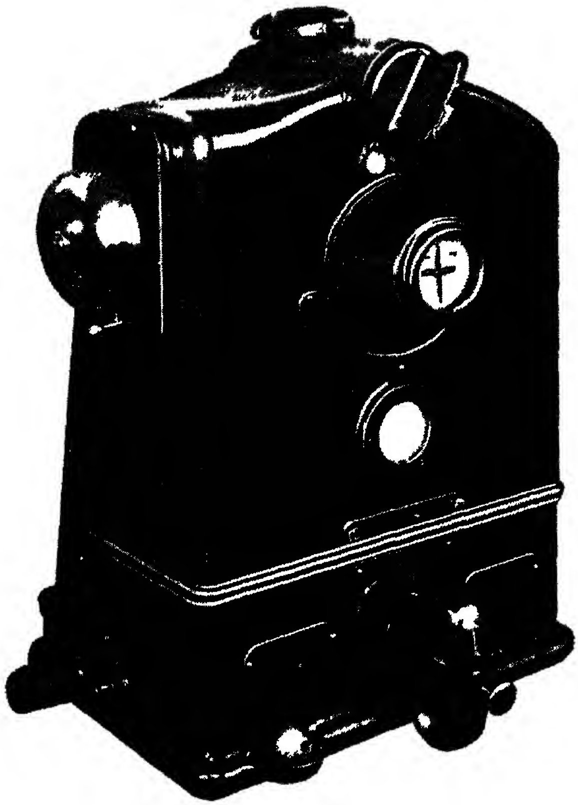


Fig 133 —Neale's Token Instrument

Neale's Instrument.—This was originally developed in India to issue card permits under the "line clear" traffic system; later it became a token instrument, and in this form has been redesigned by the Westinghouse Brake and Saxby Signal Co. The tokens are steel balls. Fig. 133 illustrates the instrument in its latest form.

Controlling Intermediate Sidings.—Sidings situated in a section are operated by a ground lever provided with a special lock which prevents the lever from being moved unless the staff, tablet, or key token, as the

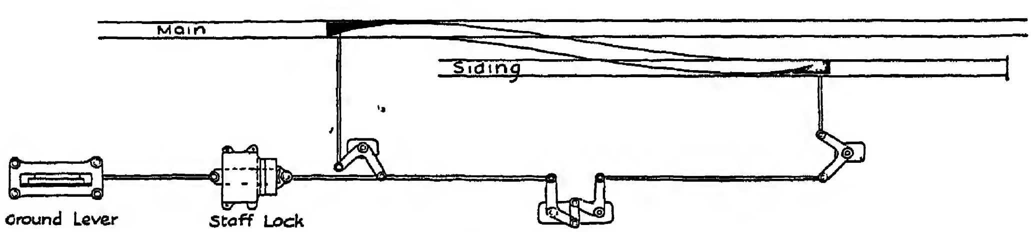


Fig. 134.—Siding Points unlocked by Staff

case may be, is inserted in it. Fig. 134 illustrates this, and fig. 135 shows one form of staff lock. Unless the lever is returned to the normal position the staff or tablet cannot be withdrawn, and when it is withdrawn the points are again locked for the main line. With the train staff and ticket system, trains carrying tickets cannot use the siding, which is often very

inconvenient and gives rise to a good deal of trouble in arranging for the staff to be available for such trains.

Sykes-Hilton Train Staff and Metal-key System.—This is designed to overcome the difficulty just mentioned, and is in use on the London and North-Eastern Railway. Instead of the usual card or paper tickets, kept in a box locked by the staff, an instrument is provided at each staff station somewhat resembling the intermediate siding key instrument seen in fig. 128, and keys are issued as tickets, it being only possible to obtain a key if the train staff is inserted in a special lock in the instrument. The keys will unlock the siding points as well as the staff, which makes the siding accessible to all trains. Electric interlocking with the block instruments to obtain lock-and-block may be incorporated with this system.

Train Remaining at Siding.—It is sometimes very convenient if a train can enter an intermediate siding and the points be restored and locked for the main line, so permitting ordinary traffic to be resumed while the train works at the siding. This can be done by placing a special staff or tablet instrument at the siding[1] in which the staff or tablet is inserted, restoring the instruments at the adjacent cabins to the normal condition. The train shut in at the siding cannot come out again on the main line without obtaining the staff or tablet from the special instrument, which in turn cannot take place unless the section is clear.

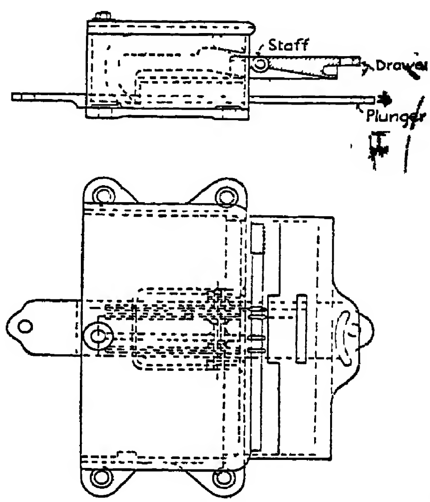


Fig. 135—Staff Lock for Outlying Sidings

Bank Engine Staff.—On sections where trains require assisting by a bank engine which does not proceed right through the section, it is necessary to guard against the instruments being restored to normal until the bank engine has returned to the starting station. This is done by providing an additional staff, normally kept in a supplementary contact box adjacent to the ordinary staff or tablet instrument, which is given to the bank engine driver as authority to proceed. Unless the bank engine staff is in position in its box it is impossible to obtain an ordinary tablet or staff at either end of the section. The bank engine is thus protected while it is in the section as long as the signalman does not hand the tablet or staff, carried by the train which the engine assisted, directly to another train waiting to proceed in the reverse direction. This is provided for by requiring signalmen always to place the tablet or staff received from a train in the instrument and obtain one in the regular way for any other train.

Interlocking Instrument with Signal.—It is possible to compel obedience to this rule by electrically interlocking the instrument with the

[1] Or by the occupation key system, see p. 110.

signal for entering the section so that the latter cannot be pulled off unless a staff or tablet has been obtained from the instrument. Thus the mere presence of the staff or tablet is not enough to unlock the lever; it must have been taken from the instrument at the station concerned. This inter-

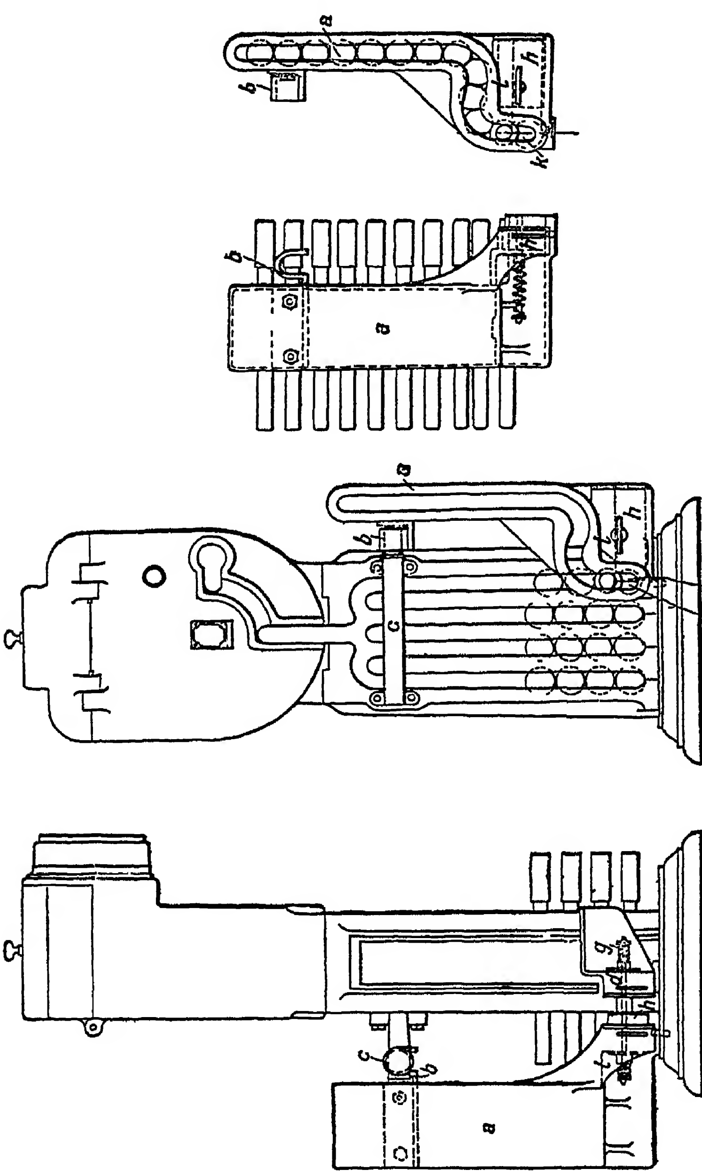


Fig. 136.—Magazine for Transferring Electric Train Staffs, Railway Signal Co., Ltd.

locking, which may be carried out in several different ways, adds very much to the safety of token instrument working. It prevents what has sometimes occurred, namely, a train entering an occupied section with a clear signal, carrying the token for the preceding section by mistake. It is applied on some railways to the ordinary train staff and ticket system, the train staff unlocking the signal lever.

Equalizing Tokens.—When there is more traffic in one direction

than another there is a gradual accumulation of tokens at one end of the section, and it is necessary, therefore, for the lineman to remove a number of these from time to time and transfer them to the other instrument. Signatures are taken from the signalmen concerned in a record book, which shows the numbers of tokens exchanged and at what time, but in spite of precautions of this kind there is always the possibility of tokens being lost or misused during a transfer, which might lead to serious results. To remove all danger of this kind the Railway Signal Co. manufacture a special magazine carrier (fig. 136) which is first fixed on the side of the staff instrument (the arrangement has so far only been applied apparently to staff instruments), and the staffs to be transferred can then be placed in the carrier, after which it is removed from the instrument. It is, however, impossible to remove the staffs from the carrier when it is by itself, and thus there is no possibility of one of them being irregularly used. When the carrier arrives at the other station it is secured to the instrument there, and this enables the staffs to be passed into it.

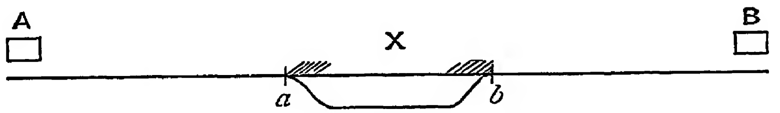


Fig. 137.—Intermediate Crossing Loop

Instrument on Platform or in Booking-office.—It is not necessary for token instruments to be in the signal box. They can be fixed on the platform and be operated by an inspector, under control from the cabin, which is very convenient at some places where it would otherwise be necessary to take the token across several lines of rails to place it in the instrument. At country stations the whole of the working is often carried out in the booking-office, but when this is the case electric interlocking between the instruments and the signal levers in the cabin is essential to really safe working.

Automatic Operator.—On colonial railways it is very difficult and sometimes even impossible to station operators at all places where passing loops are required, and for some time this militated against the use of token instruments on such lines. Both Tyer & Co. and the Railway Signal Co. have, however, devised apparatus whereby a tablet or staff can be obtained from their instruments without any operator being necessary at the other end of the section, provided the correct conditions obtain at the time. In this way the guard of a train can himself obtain the staff or tablet at each crossing loop and restore the one relating to the section just passed through. These devices are very useful for light railways.

Intermediate Crossing Station.—An intermediate crossing station to be used only by certain trains can be worked without any token instruments being fixed at the loop. This is illustrated in fig. 137. The ordinary section extends from A to B, and trains carrying (say) a tablet travel on the direct line between the two stations. At A and B there are subsidiary

instruments, each containing one special tablet available only between A and X and B and X respectively. These are normally locked. When two trains are required to cross at the loop X, one signalman (say A) obtains a tablet in the usual way, and inserts it in the special instrument. This enables him to obtain the AX tablet and to give permission to B to obtain the BX tablet, at the same time rendering the ordinary instruments inoperative. The two trains proceed, carrying the special tablets (which control the points *a* and *b*) to the loop where they cross. The tablets are exchanged there, and are thus returned eventually to the issuing stations, where they are restored to their own instruments. This enables the A to B tablet at A to be put back into the ordinary tablet instrument, returning everything to its normal condition.

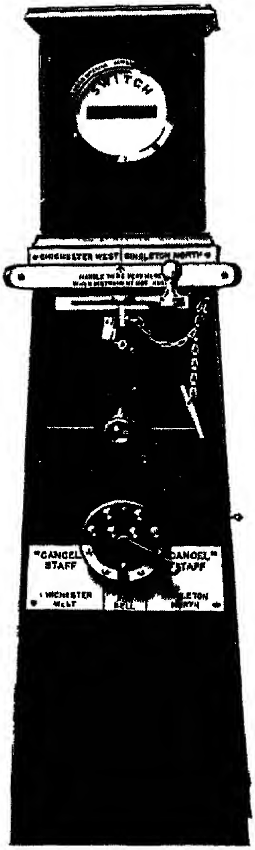


Fig 138 —Intermediate Switch for Non-crossing Station

Non-crossing Block Post.—In order to allow trains to follow one another at a lesser interval than that separating two crossing loops, token instruments are sometimes fixed at stations or block cabins where there is no loop. When this is done it is necessary to provide some arrangement in order to prevent two trains approaching the intermediate station from opposite directions, as they would be unable to pass one another. One arrangement that is in use both for staff and tablet instruments is illustrated in fig. 138, designed by Sykes Interlocking Signal Company. It consists of a pedestal supporting a Sykes locking instrument, beneath which is a switch which is normally in the centre position. The locking instrument is normally " free ". Let us suppose that this apparatus is installed at a non-crossing electric-staff station Y, situated between two crossing stations A and B. If a train is to proceed from A, Y must, before he can give permission to A to withdraw a staff, place the switch in the A position and lock the instrument by raising the handle underneath it. He then gives the permission in the usual way. While the Sykes instrument is locked the switch is locked, and thus cannot be placed to the B position, preventing permission from being given to B to withdraw a staff. The instrument is released and the switch unlocked when either (*a*) the staff from A brought by the train is placed in the instrument working to A, or (*b*) the staff is replaced at A, should the train be cancelled. The working is similar where tablet instruments are used, and Tyer & Co. and the Railway Signal Co. manufacture apparatus to accomplish the same results as that realized by the Sykes apparatus. It will be seen that when the train arrives at Y and the staff from A is placed in the instrument, the switch could then be

placed to the B position and a train be accepted from B. This is not very likely to occur, as in the ordinary way the signalman would already have obtained a staff for the YB section from his instrument for the train to proceed with. On part of the London and North-Eastern Railway there is an arrangement in use which covers this point. It is applied to tablet instruments. Electric treadles are fixed on each side of the non-crossing station, and so arranged that while a train is at the station it is impossible to give permission in either direction for another to approach, but when it has proceeded on its way over a treadle clear of the station, then permission can be given for another train to enter the section which is clear. In practice, however, the Sykes apparatus has been found to meet all ordinary requirements.

Switching Out Tablet and Staff Stations.—This is more difficult than switching out cabins on double lines, where all that is necessary is to clear the signals and connect the adjacent cabins on a through circuit. In the first place, when a loop cabin is closed all trains must run through on the same line, and signals for opposite directions be pulled off simultaneously, which in the ordinary way is impossible. In addition to this a driver running from (say) A to D, past two closed loop stations B and C, must have as his authority a token applicable from A to D, and possession of this must guarantee not only that the section AD is clear, but that the crossing loops and signals at B and C are set for through running and cannot be interfered with in any way. Apparatus to accomplish this was first introduced in connection with tablet instruments, but has since been designed for use with other token instruments.

McKenzie and Holland System.—This is developed from the original Dutton and Neville system, and has been modified recently by Sykes Interlocking Signal Co. If there are three tablet stations A, B, and C, and it is desired to be able to close B at certain times, an additional tablet instrument is placed at A and C, for issuing what are known as "long section" tablets, which are generally square shaped to make them distinctive and apply to the whole section AC. An additional line wire is run from A to C, but the circuit is normally broken so that the long-section instruments cannot be operated.[1] At B an additional lever called the master or closing lever is provided in the locking frame which controls the mechanical locking arrangements in the following manner. When it is normal it allows the locking to operate in the usual way. When in the centre position it enables the signals to be pulled off for opposite directions at the same time and for one line of the loop, and when in the reversed position it back-locks the signals in that condition. An additional signal is provided at one end of the loop[2] for indicating that the right-hand direction

[1] In the McKenzie-Holland-Edmonds system an extra line wire is not required, but two strengths of line current are employed to differentiate between certain signals and movements.

[2] It is understood, that the Ministry of Transport do not insist on this extra signal, but it would seem better practice to provide it and not make the ordinary home signal read two ways.

is to be taken, and in fig. 139 is seen the condition of the signals when the station is closed. The closing lever is equipped with two key locks, somewhat resembling Annett's lock, as shown in fig. 140, and the keys, called

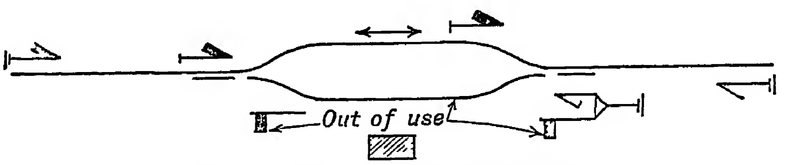


Fig 139 —Signals at Closed Crossing Loop

the "short section" and "long section" keys, work in conjunction with a special instrument, shown in fig. 141, which is under the control of the cabins A and C, and in turn governs the working of the tablet instruments. Normally when B is open the short-section key is locked in this instrument, and the long-section key is locked in its place on the closing lever, which is also locked normal. To close B, the AB and BC tablet instruments must be in the normal position, that is no tablet must be out, and if this is so, A and C can, by pressing their bell keys, permit B to take the short-section key out of his instrument, which breaks down the short-section tablet instruments. The short-section key is then placed in the lever lock, and the closing lever can then be pulled to the middle position. The signals are then pulled off as in fig. 139, and then the closing lever is fully reversed. This releases the long-section key which is inserted in the instrument and becomes locked, completing the AC tablet circuit, so that through working can take place. To open B the process is exactly reversed. Any number of stations can be closed in rotation with this system. As the interlocking is realized by means of the keys it is evident that the tablet instruments and special instrument can be in the booking-office and still properly control the signal cabin. When they are in the cabin, however, the keys and key locks are not really necessary, and the special instrument can interlock directly with the closing lever, as in Sykes' system, illustrated in fig. 142.

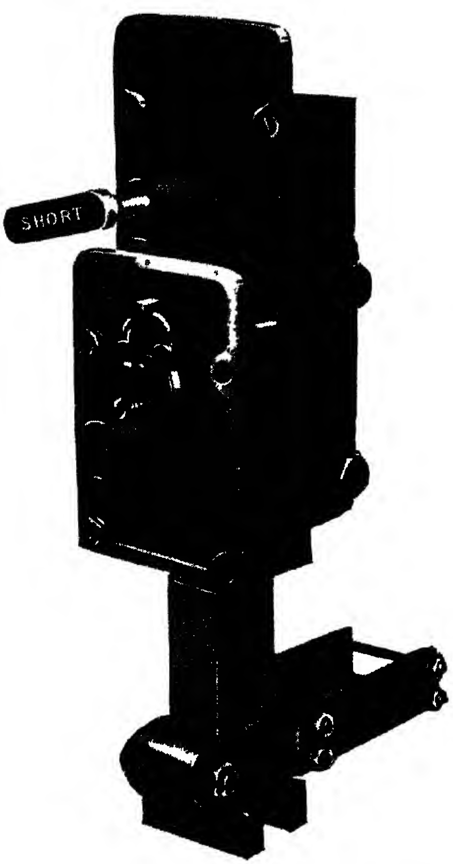


Fig 140 —Double Key Lock for Closing Lever

Tyer's System.—In this system the closing lever is controlled directly

by a handle, electrically controlled and mounted on a pillar, the movements of which are substantially similar to those employed in Sykes' instrument, and realize the same programme of working.

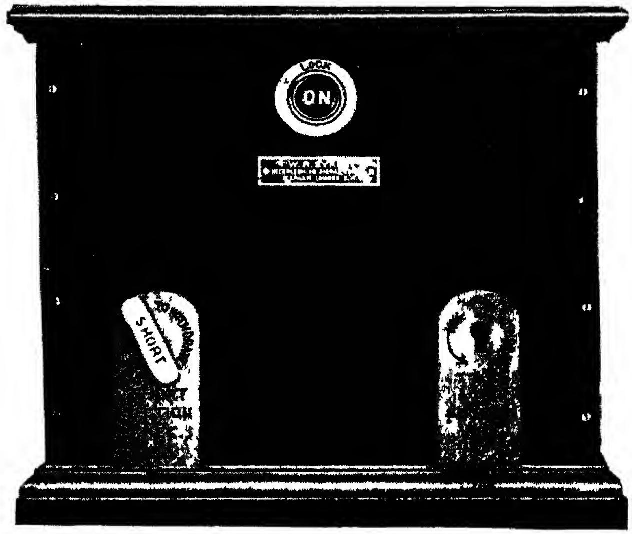


Fig. 141—Key Tablet Closing Instrument

Railway Signal Co.'s System.—This differs from the preceding systems in that the long-section instruments are normally out of phase, a token (in this case an electric staff) for the long section being normally locked in a drawer of a special apparatus which is placed at one end of the long section (fig. 143). At the intermediate stations another apparatus (fig. 144) is placed which contains two drawers, and a special handle which operates the interlocking and controls the setting of the loop and the signals in a similar manner to the closing lever employed in other systems. In order to close the intermediate station, the signalman obtains a short-section staff for the section most remote from the terminal station where the apparatus shown in fig. 143 is fixed, and inserts it in the upper drawer of the switch apparatus, which enables the closing handle to be operated and the points and signals to be correctly set. The final movement of the handle allows the upper drawer to be pushed right home, where it becomes automatically locked, and at the same time connects up the long-section instrument circuit. The terminal station also places a short-section staff in the lower drawer of the terminal apparatus, and this enables the long-section staff to be withdrawn with the consent of the other terminal station, provided that the switching out

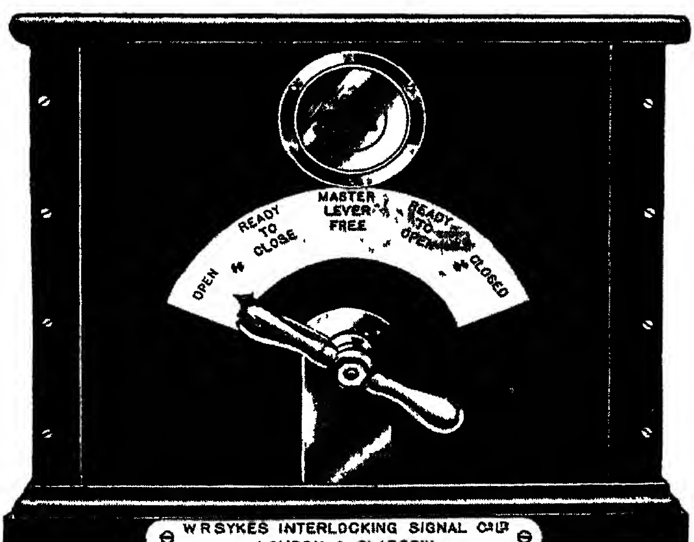


Fig. 142.—Sykes' Switching-out Instrument

movements have been made as described at the intermediate station. The long-section staff being placed in its instrument, through working can take place.

Switching in is accomplished by the terminal station placing a long-section staff in the upper drawer of the terminal apparatus, which becomes

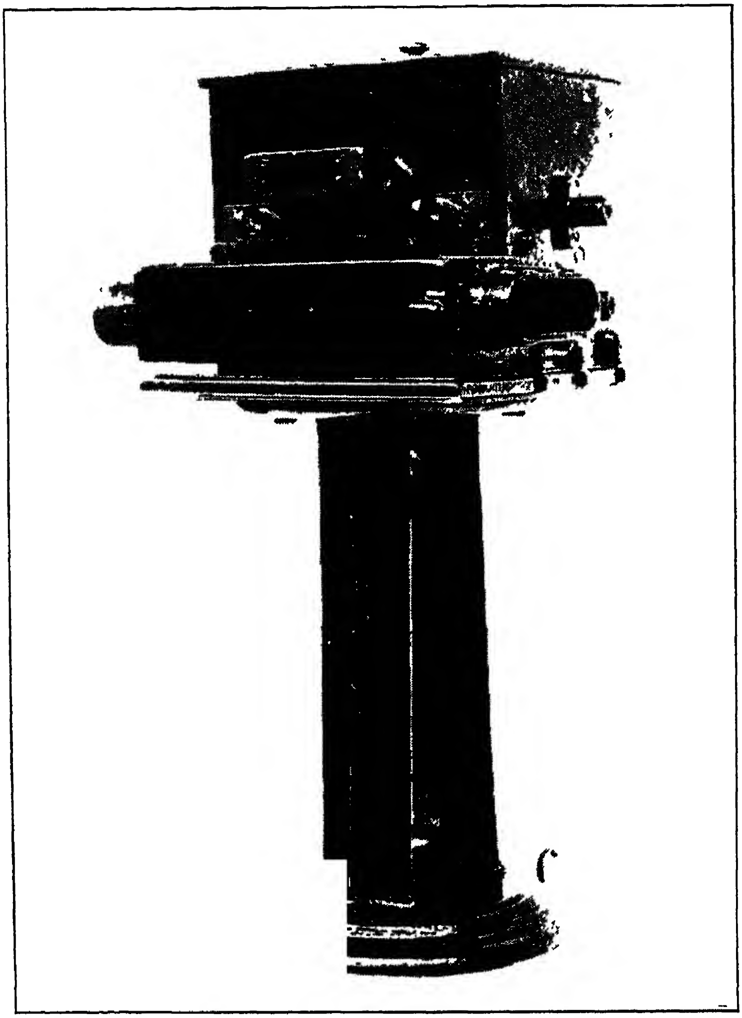


Fig. 143—Terminal Switching Control when Normal, i e Short-section Working in Force

locked in and allows the short-section staff to be withdrawn, which is then placed in the short-section instrument. The intermediate station then obtains a short-section staff for the section between it and the terminal station, and places it in the lower drawer of the switch apparatus, which allows the station to be switched in and the interlocking handle to be operated, finally liberating the short-section staff for the next section, which was placed in the upper drawer when the cabin was closed. This in turn liberates the lower drawer and thus both short-section staffs may be put back in their instruments. This process is repeated from station to

station, if more than one intermediate station exists, until all the short sections are restored to normal. Thus, although switching out can take place in any order, switching in is accomplished in a definite sequence.

Mechanical Switching Out.—This is also due to the Railway Signal Co., and is very simple in principle. It was designed many years before

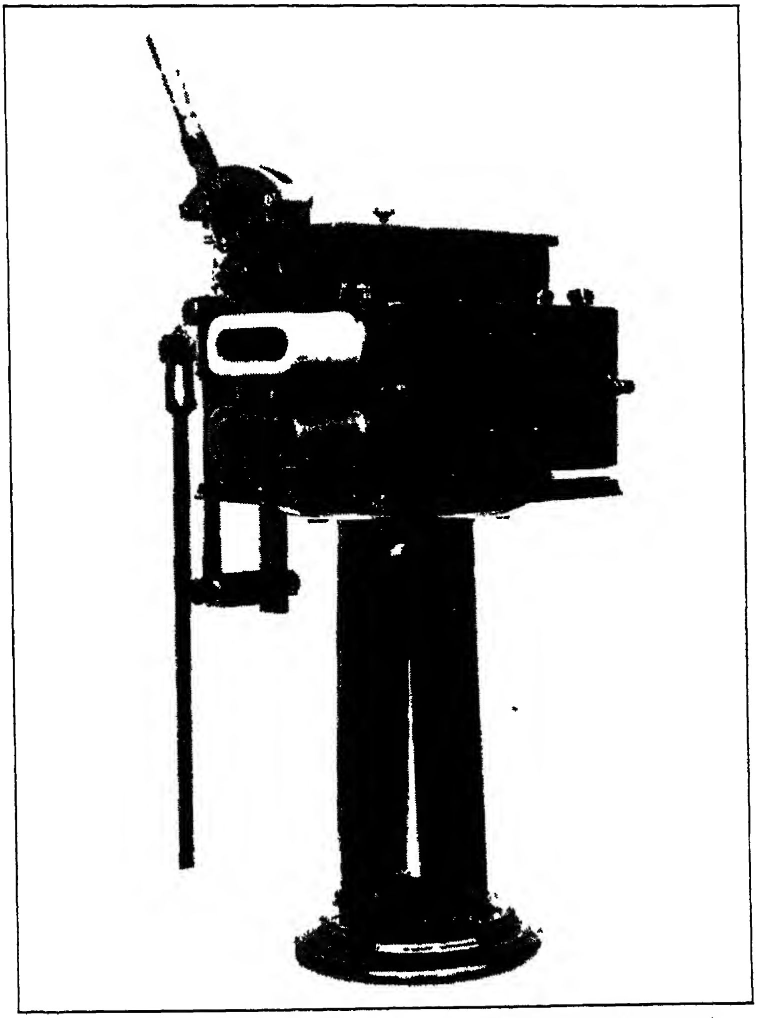


Fig. 144.—Switching-out Control at Intermediate Station when Normal

their standard method just described. The long-section instruments are normally out of phase and a long-section staff is contained in a drawer at the switch station, which may be called Y, situate between A and B. Y cannot be closed at any time, but only when a train is passing which can take the long-section staff away from there. Let us assume it comes from A. On arriving at Y the signalman takes the AY staff, and, having obtained a YB staff, inserts both in drawers in the mechanical switch apparatus, which liberates the AB staff. This is handed to the train, and on its arrival at B is placed in the long-section instrument there. To open Y the last

long-section train delivers up the AB staff there, which is placed in its drawer, freeing the two short-section staffs, one of which is handed to the train and the other put into its own instrument. A modification or extension of this system enables several intermediate stations to be closed. Electrical closing systems are better than mechanical, being much more flexible.

Staff only for Long Section.—In this arrangement the through working is carried out on the simple staff system, a staff being liberated

Fig. 145.—Tyer's Key Token Instrument for Single Lines

from a special instrument when switching through is accomplished. It is only suitable where the through traffic is perfectly regular, as the staff must come from and return to the same station.

Intermediate Sidings in Long Section.—These can be worked if the ground levers are arranged to be unlocked by either a long- or short-section tablet or staff. The points at the closed loop stations can, by a special arrangement, be operated by trains carrying a long-section token.

Tyer's Key Token Instrument.—This achieves the same object as a tablet or staff instrument but the tokens are keys, which are very suitable for controlling intermediate sidings. Let A represent the signal cabin at one end, and B the signal cabin at the other end, of a section of

single line, controlled by Tyer's key token instruments of the type fitted with polarized lock and three-position electric indicator (fig. 145). The electrical diagram with magneto working is shown in fig. 146.

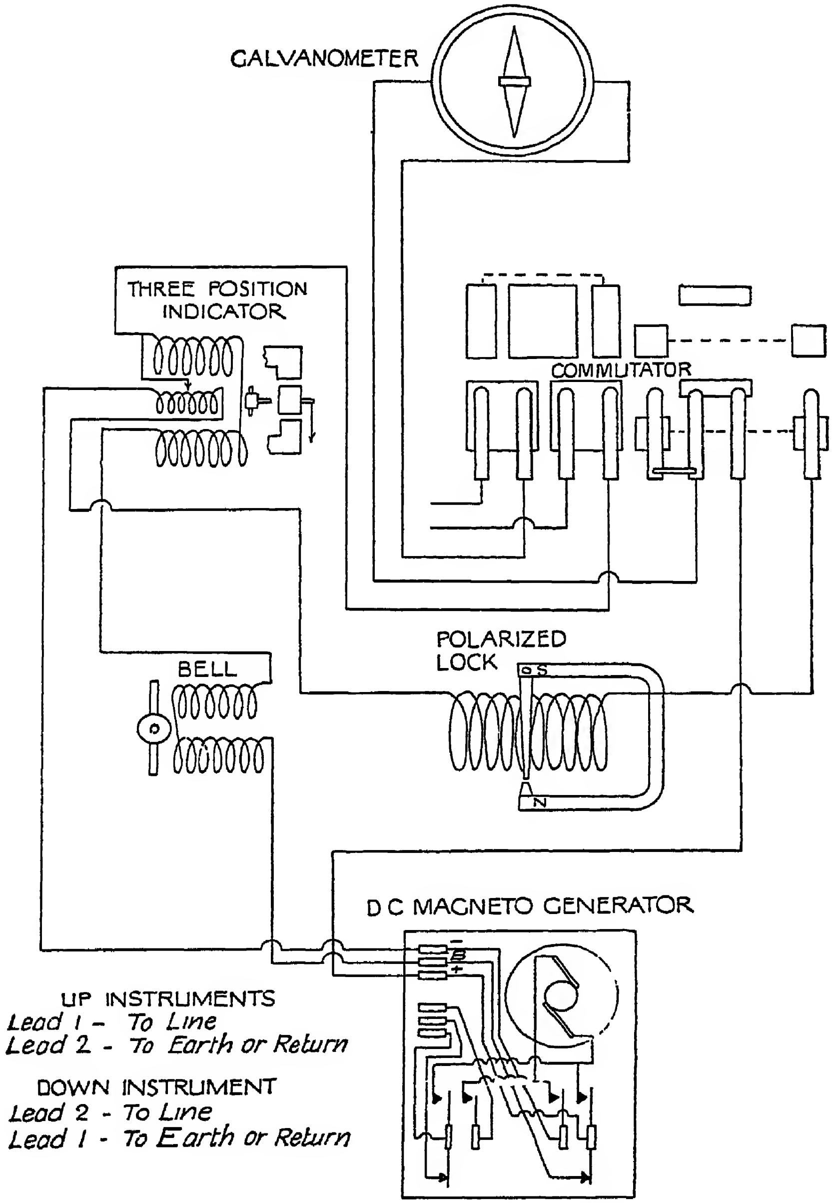


Fig. 146.—Electric Wiring Diagram for Tyer's Key Token Instrument

When the signalman at A wishes to send a train to B, he signals, as per code, on the bell key of the key token instrument, which rings the single stroke bell at B once at each depression.

If the section is unoccupied (which is seen at a glance by the electric indicator showing " line normal "), and he can accept the train, the signal-

man at B replies on his bell key as per code, keeping the bell key depressed for a short while after the last beat of the code signal.

The signalman at A then slides a key token along the grooves of the magazine of the instrument into the key way, and starts to turn in the anti-clockwise direction.

The key way is actually the head of the rotary commutator, and therefore a key token can neither be inserted nor withdrawn without the correct operation of the rotary commutator.

Before the signalman at A starts to turn the key token, the current which is being received on the line wire from B passes through the contacts of the commutator to the coils of the block bell, but as soon as he starts to turn, the circuit to the bell is broken, and the current received from B is passed through the commutator to the coils of the electromechanical polarized lock. If the current is of the correct polarity (determined by the contacts on the commutators on the instruments at both ends of the section) the armature of the polarized lock will become attracted, and the further

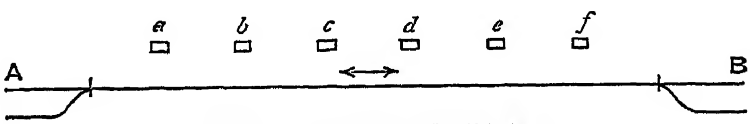


Fig. 147.—Occupation Key Working

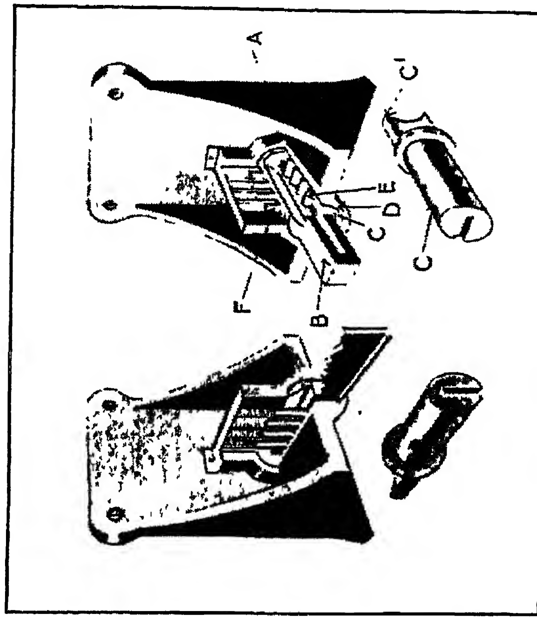
turning of the key token lifts the locking mechanism and the signalman at A is able to complete a half turn and obtain the key token. The "train on line" signal is then given and acknowledged in the usual manner on the block bells, and the indicators show the state of the traffic. The indicator at A will show "train going to B", and the indicator at B "train coming from A". The indicators, which are operated by a momentary current, remain in these positions until the key token is inserted into one of the instruments, when they will return to "line normal".

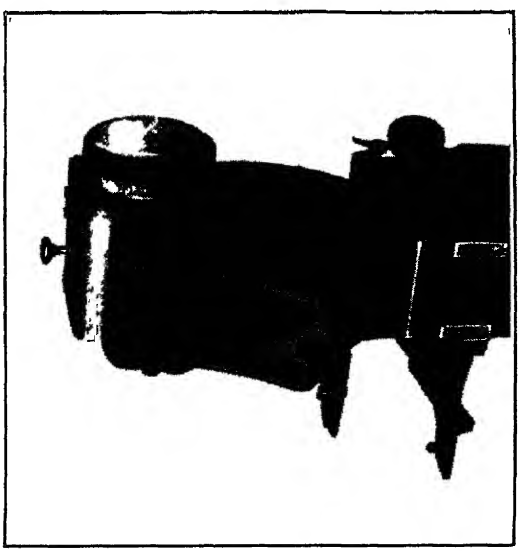
When a key token is taken out at B the indicator there will show "Train going to A," and the indicator at A will show "train coming from B".

There being no local receiving circuits on this type of instrument, it is particularly adaptable for being operated with magneto generators, the only difference in the instruments for battery and magneto working being the resistance of coils and the type of ringing key, which in the case of magneto working is combined with the magneto.

Occupation Key.—This is supplied by Tyer & Co., and affords a simple means of controlling branch lines and intermediate sidings, and also for enabling permanent-way gangs to work on a single line without having to be protected by flagmen. It is applicable to a tablet, staff, or any other kind of token instrument. Fig. 147 shows a single line between A and B, at six intermediate points along which (*a*, *b*, *c*, *d*, *e*, and *f*) are placed occupation key instruments. If a ganger wishes to place a trolley on the rails and run (say) from *b* to *e*, he telephones to A and B,

who can, if no regular token is in use, give him permission to obtain the key at *b* (which he inserted there when he arrived), and the withdrawal of the key makes it impossible for a through train to be signalled. On arrival at *e* the ganger, when the trolley is clear of the rails, inserts the key there, which restores the circuits to the normal condition. Possession of the key, therefore, affords complete protection to the trolley, and flagmen are not required. The occupation key system is largely used on the Great Western Railway for the protection of permanent-way gangs. It is also employed on the Southern Railway to control the junction of the Dungeness Branch with the line from Lydd to New Romney, where formerly a signal box, Romney





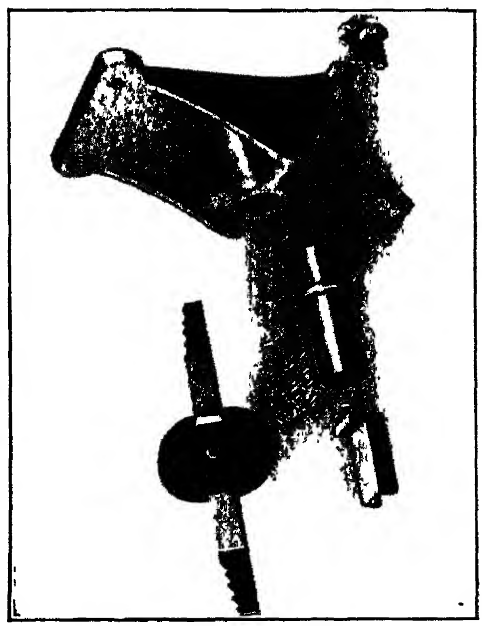


Fig 148.—Pilot Staff and Lock

Junction, had to be maintained. The junction points and signals are operated locally and are controlled by the key, the guard of the Dungeness train being responsible for working them. The Dungeness train receives the key at Lydd, and in clearing the junction, the points and signals are set for the main line, and the key inserted in the occupation instrument,

which re-establishes tablet working between Lydd and New Romney. Considerable economies are realized by this method of working, a signal box being entirely dispensed with.

Pilot Staff.—When the staff, tablet, or other token system fails on a single-line railway, it is the rule to employ a single-line pilotman, who, whilst the staff or tablet is not in use, has to accompany or start every train over the section. On single lines fewer men are employed than on double lines, and it may so happen that, should the station-master act as pilotman, the only available person on the station except the signalman, who must not leave his box, will be away, and important business for the company and for the public may be neglected. The Railway Signal Co. have designed an arrangement known as the pilot staff, to take the place of the pilotman. It is illustrated in fig. 148. A lock A is mounted on the side of the staff instrument normally containing half of the pilot staff, the other half being similarly attached to the instrument at the other end of the section. The complete pilot staff is formed by fastening the two halves together, which, when removed from their respective instruments, actuate a projection C′ covering the slot through which the ordinary staffs are taken out. Thus no such staff can be obtained while the pilot staff is in use, nor can the latter be obtained without a visit to each end of the section, as required by the regulations for pilot working.

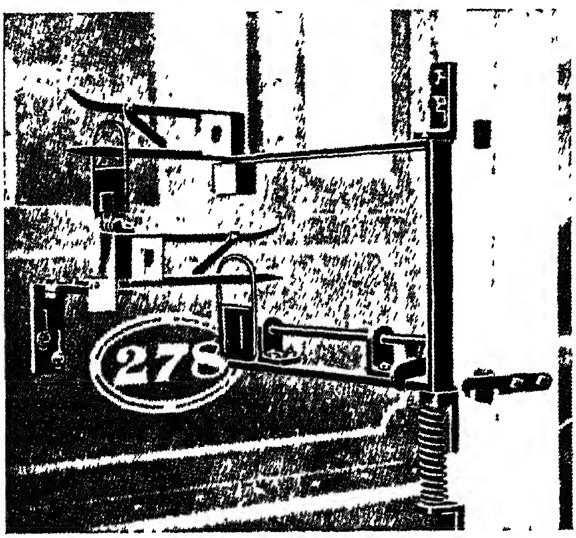


Fig 149—Tyer's Exchanger in Operation

Exchanging Tokens.—There is no difficulty in exchanging tokens when trains stop, but where through trains run, the speed must be considerably reduced to avoid injury to the signalmen and train-men, especially at night, which causes a great deal of delay and prevents single lines being worked expeditiously. To overcome this, various mechanical appliances have been designed to enable the exchange to be made automatically, on the principle of the mail-bag catcher, or partly automatically. When entirely automatic apparatus is used, full speed can be maintained, and express services can be operated without much difficulty. Only a few of the devices in use can be referred to here.

Tyer's Exchanger.—This is illustrated in fig. 149, at the moment of exchanging tablets. Spring-catch jaws are fitted on the locomotive and on the ground pillar arm, with spring clips for holding the tablets which

are to be exchanged. The fireman sets the locomotive apparatus ready before reaching the tablet station, where the signalman similarly prepares the ground apparatus, turning the swinging arms out towards the line, where they are held by a catch. The jaws engage with the loops on the tablet holders and draw these out of the clips, which releases the catch and allows the arms to swing clear of the line under the action of the spiral spring seen in the figure. The apparatus can be arranged to work for either direction of running as required, and is very simple in construction.

Whitaker's Exchanger.—This is illustrated in fig. 150. The ground mechanism consists of a standard which is fixed as near to the running line as the structure gauge will permit. Into this is fitted a vertical spindle carrying two horizontal arms, one above the other. The upper arm has a pick-up jaw and the lower one a delivery jaw. The spindle rotates by the action of a pair of bevel wheels and a weighted lever, so that the arms are turned either parallel with the running line when not required for use, or at right angles to the line when in the operative position.

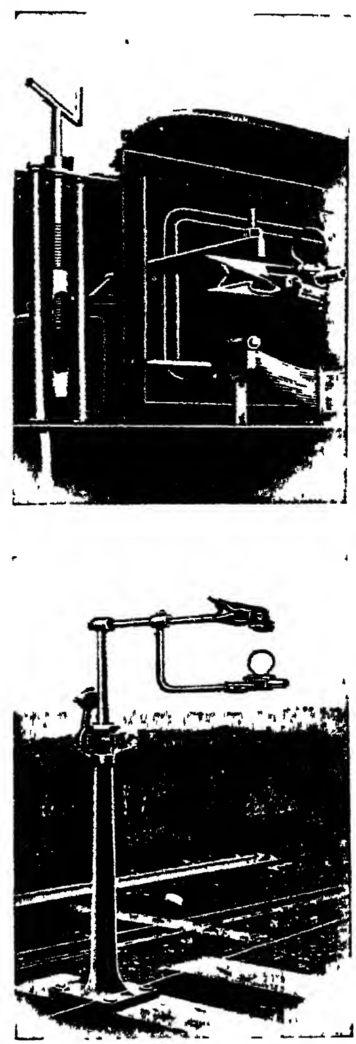


Fig. 150.—Whitaker's Exchanger

The apparatus on the engine consists of a horizontally slidable bar, passing through the side of the cab or tender, carrying a combined pick-up and delivery jaw.

Train staffs may be fixed in the jaws direct, but tablets must be placed in a pouch with a hoop handle before being fixed in the jaws.

Manson's Exchanger.—The standard on the ground has a horizontally slidable bar, carrying the pick-up and delivery jaws, which is weighted to draw back clear of the line when not in use.

On the engine a similar arm, carrying the combined pick-up and delivery jaws, is pivoted in such a way that it can be lifted up close to the side of the cab when not required for use.

Great Western Apparatus.—This is not an exchanger in the strict sense, but is an arrangement for facilitating hand exchanging. A post about 9 ft. from rail level is provided with a curved arm to receive tokens, projecting out of a square pad. A lamp-post is fixed a short distance away, so as to throw a strong light upon the above-mentioned post, and

a third post is fitted with a cast-iron socket in such a position that a token inserted in it is easily within reach of a fireman. This post also has a lamp which throws a strong light upon the token to be picked up.

Henry Williams' Apparatus.—The post near to the line has a large hook to receive the tokens, this hook being hinged so that it may be swung clear of the line when not required for use. It also has a jaw for holding a token in readiness for a fireman to pick it up. Each engine carries a catching pole adapted to be held over the side of the tender by the fireman. This pole is fitted with a half-hoop with two fingers which prevent the token from coming out again after being picked up, and at the back of the hoop is a jaw to hold the token to be given up.

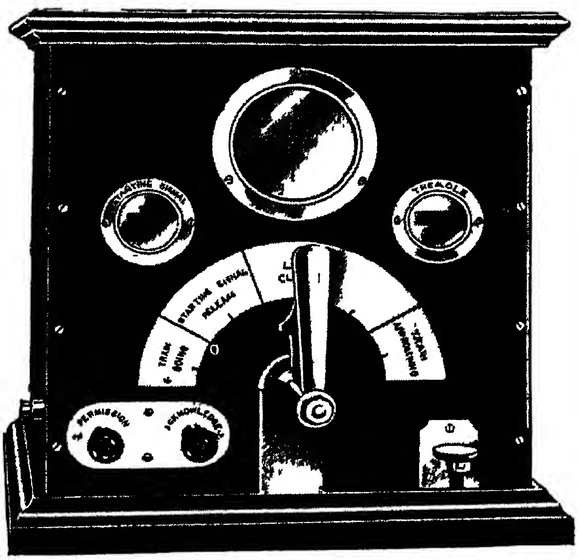


Fig. 151.—Sykes' Non-token Single Line Instrument

Lock-and-Block System.—On the Continent, except in Russia, tablet and staff working is little used. Important single lines are usually controlled by some form of lock-and-block. In Great Britain such a method is not officially recognized (see Appendix), but certain installations have been allowed to be brought into use, notably on the Cairn Valley branch of the London Midland and Scottish Railway, where Sykes' system is used. Single line lock-and-block systems are generally called "non-token" systems.

Comparison with Token Working.—The only absolute token system is the simple staff system, as there is then only one token to each section. In electric systems, the token loses its absolute character and becomes simply a register of the passage of a train, and since there is a number of similar tokens to each section it is evident that the security really rests on the mechanism of the instruments, which is intended to prevent more than one token being obtained at a time. If equally reliable lock-and-block mechanism can be made, then the token becomes unnecessary. If there is no token to exchange the whole working is made quicker and simpler, and the outdoor signals constitute everywhere the driver's sole authority to proceed, whether the line be double or single.

Sykes' System.—This has been adopted in Russia and Japan as well as in Great Britain. The latest form of instrument is shown in fig. 151. Two line wires are usually employed, the bell line being separate, but this is not absolutelv necessary. The handle is normally at "line closed"

when all signals are locked, and it has three other positions, viz. "train approaching", "train going", and "starting signal release". The instrument is mechanically and electrically interlocked with the signal levers, and no movement can take place at either end of the section unless both signalmen co-operate. When a train has to proceed from A to B (fig. 152), B first places his handle to "train approaching", which releases his home signal, and can then allow A to turn his handle through "starting signal release" to "train going". A's starting signal is now free and can be pulled off and returned to danger as often as A pleases until the train in starting actuates treadle *a*, when the signal becomes absolutely locked. A's handle is likewise locked in the "train going" position. The train arriving at B actuates treadle *b* and unlocks the instrument handle, which B returns to "line closed" after replacing his home signal lever. He can then give permission to A to return his handle to "line closed". While the instruments are set ready for the dispatch of a train, they can be returned to their normal position provided that all signals are at danger and no train has actually started, but such cancelling cannot take place if a train has entered the section. At certain stations it may be advisable

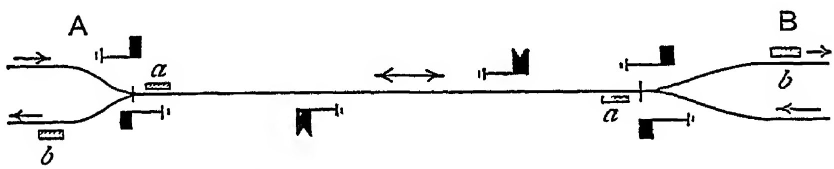


Fig 152.—Non-token or Lock-and-block System

to return the starting signals automatically by means of a replacer, but this is not essential at every station as no second train can be accepted unless the signals in both directions are at stop.

Siemens & Halske System.—This is widely used in certain Continental countries, and is operated by magneto generators. In its latest form it has one rather peculiar feature, which is that it allows trains to be accepted in opposite directions at the same time. For instance if a train be travelling from A to B and one is waiting to pass it at B, that train can be accepted by A in readiness, but B cannot actually make use of this acceptance until the AB train arrives, when he can dispatch the BA train without any further necessity of communicating with A. The object of this is to save time at crossing stations, which is important when trains are late, and enables the A signalman (who at country stations is often the station-master) to attend to other work about the station without being called again to the instrument. In this latest system an acceptance which has been obtained can be given back at any time till the starting signal is pulled off, an improvement over the original Siemens & Halske system.

Intermediate Sidings with Lock-and-Block.—There being no token with which to unlock the points at intermediate sidings, it is necessary

to employ an electrical control, interlocking the siding with the signals and instruments at each end of the section. Fig. 153 illustrates the special siding instrument used in Sykes' system, which is placed in a lock-up hut or pillar at the siding, and unlocks the siding points when permission is received from the adjacent cabins. Unless the siding instrument is

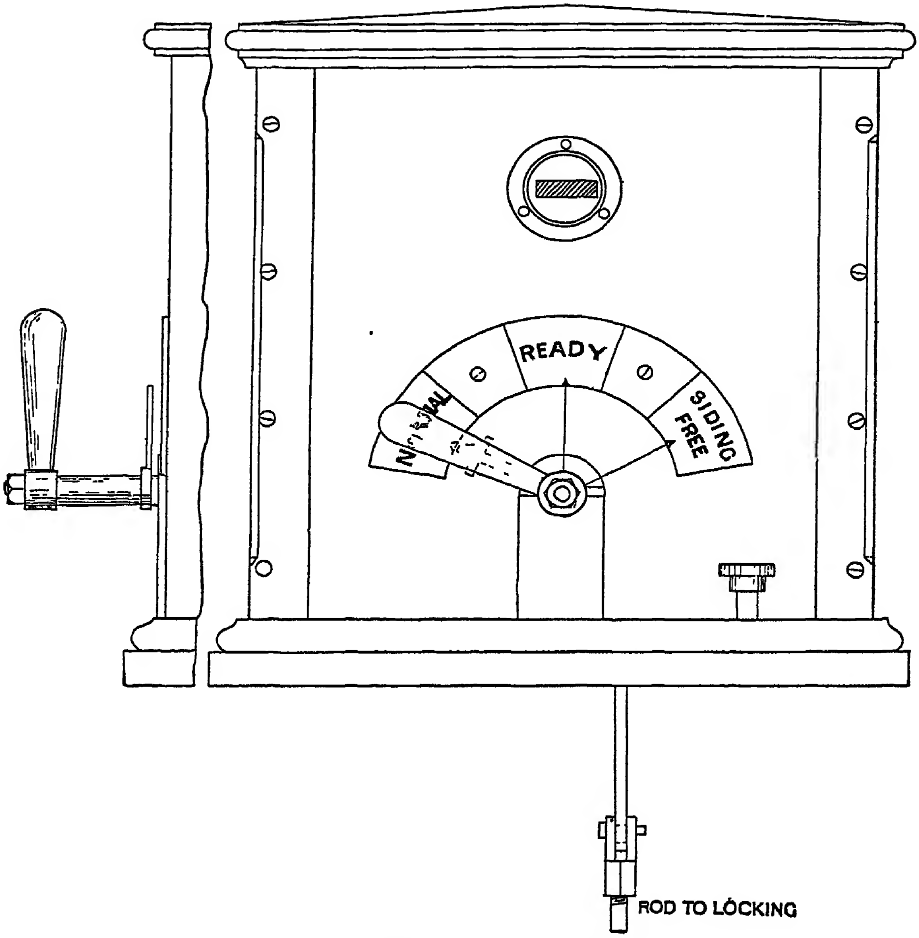


Fig 153.—Siding Control Instrument

restored to normal, locking the points, the through working cannot be resumed.

Switching Out Loop Stations.—This is accomplished by employing a special closing instrument and closing lever in the same manner as with the tablet system, but no extra block instruments are required. Any station can be switched out, as on double lines, the block instrument working with the next open station, whatever this may be. This is a valuable feature of non-token working. In token working the long or switched-through sections must always be the same, since these are limited by the points where the long-section instruments are placed.

Transient Track Circuit.—The transient track circuit, mentioned

on p. 136, can also be applied to single lines to form a non-token block, giving complete track circuit protection throughout the section, the line being electrically tested and proved clear before a train is dispatched.

Automatic Signals on Single Lines.—Automatic signalling is extensively used in the United States to protect single lines, and is finding much favour in some of the English colonies (see Chapter X).

CHAPTER IX

Track Circuits

I.—DIRECT CURRENT

Principle of Track Circuit.—This consists in making the actual presence of a train or vehicle on a given section of line give a continuous indication of the fact and lock or otherwise control the signals, block instruments, &c., applying to such section, so that it is impossible to admit a second train to it until it is clear throughout its entire length. The control is thus effective the whole time the section is occupied at any part, even by a single pair of wheels.

Closed Track Circuit.[1]—This is illustrated in fig. 154, the distance x

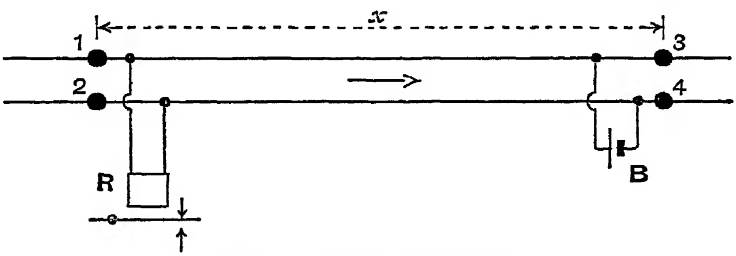


Fig. 154.—Closed Track Circuit

being track-circuited. The ordinary fishplates are replaced at points 1, 2, 3, and 4 by special insulating fishplates or joints. A relay R is connected to the rails, at the entering end of the circuit as a rule, and a battery B is similarly connected at the opposite end. The intervening rail joints are bonded to ensure good electrical connection. The battery B normally energizes the relay R, which by means of a local circuit may operate an indicator, lock a lever, &c., according to requirements. When a vehicle comes on the insulated section, the relay is shunted, as the mass of the

[1] A closed track is normally energized. Open or normally de-energized circuits, which require the presence of a vehicle to energize them, are used for a few minor purposes, but as the breakage of a connection can cause them to show the track clear when it is not, they cannot compare with the closed circuit for general use. This does not refer to "transient" circuits, for which see p. 136. For the purposes of explanation, battery-operated circuits are considered, but, as will be seen later, other sources of energy may be employed.

wheels and axles offers practically no electrical resistance, and releases its armature, changing the indicator in the cabin, locking the lever, &c., as the case may be. The relay thus reflects the condition of the section,

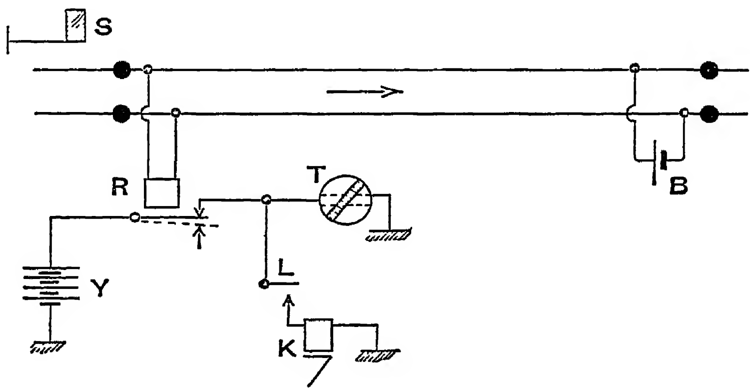


Fig. 155 —Local Circuit

"clear" or "occupied". Instead of insulating both rails, one only may be provided with insulated joints, forming what is called a single-rail track circuit. It is better to insulate both rails, whenever this can be done.

Local Circuit.—An example of this is given in fig. 155, where the track relay R controls the indicator T and the lock K on the lever of signal S, these being fed by battery Y over the armature of the relay. The lock is not permanently in circuit, but is lifted when the track is clear by the closing of contact L, which may be a hand, foot, or latch contact. It will be seen that signal S cannot be pulled off while the track circuit is occupied.

Fig. 156.—Indicator for Line Relay

Repeater or Line Relay.—In a number of cases it is found more convenient to have a relay in the signal box worked by the local circuit from the track relay, and to control the lever lock, &c., through the armature of this relay, which is known as a repeater or line relay. This is particularly the case in complicated installations as it reduces the amount of external wiring necessary. The line relay may itself mechanically operate an indicator, as in fig. 156.

Cut Section or Relayed Section.—When a section is too long to operate as one track circuit, it is divided into two or more separate circuits which work as one, the connections at the dividing point being arranged

as shown in fig. 157. The relay RB, when de-energized, disconnects the battery for section A and short-circuits that section, so holding relay RA de-energized. Section A and B must both be clear before relay RA can again attract its armature.

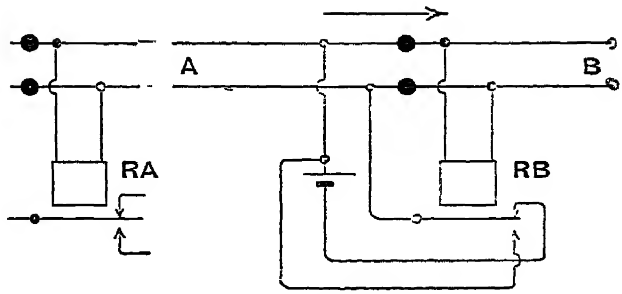


Fig. 157 —Cut Section

Track Circuit through Points.—When points occur in a track circuit additional insulated

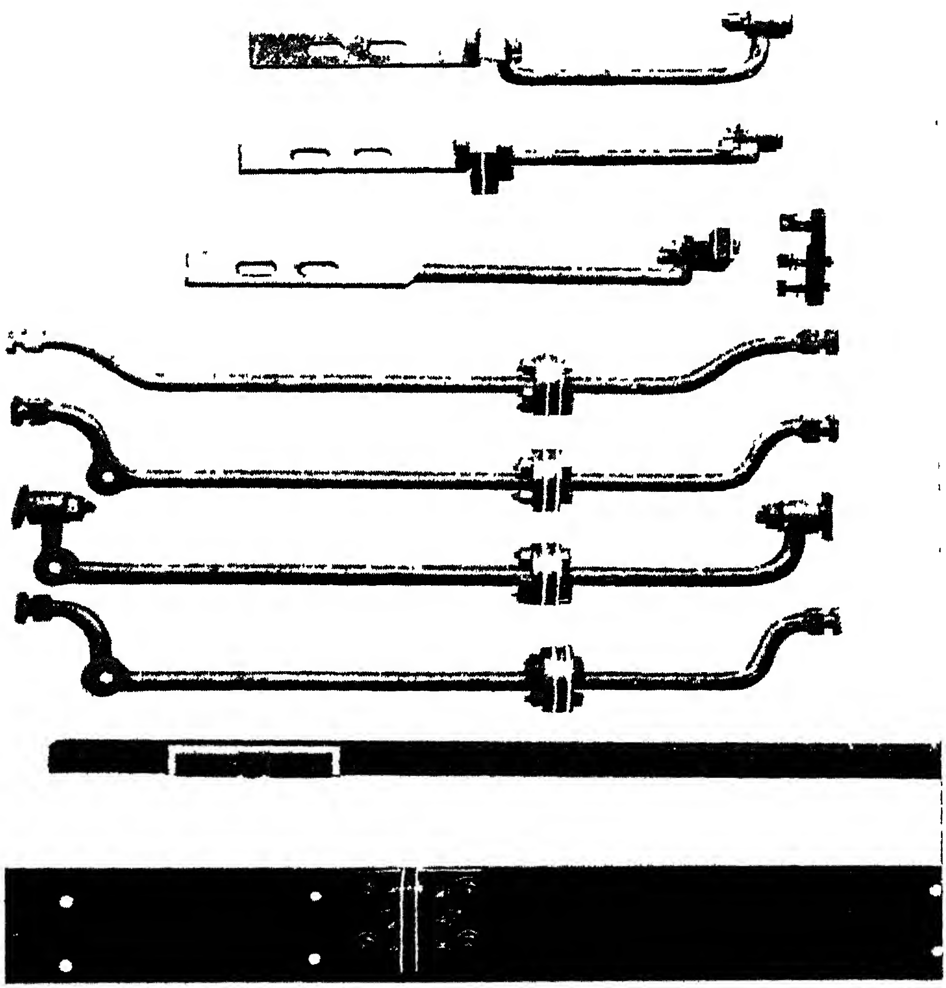


Fig 158 —Insulated Fittings

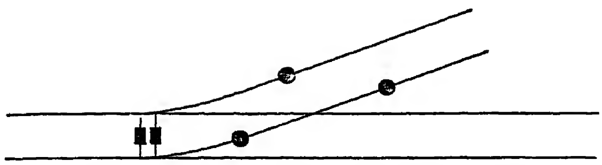


Fig. 159.—Points in Track Circuit (simple case)

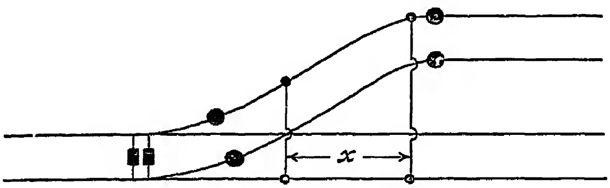


Fig. 160.—Shunt Fouling Circuit

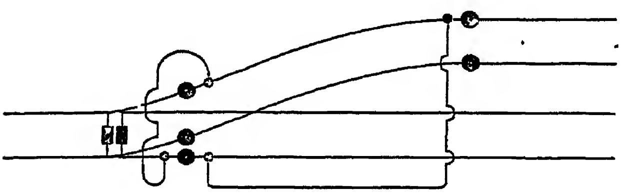


Fig. 161.—Series Fouling Circuit

fishplates are required, and the force and tie rods, &c., must likewise be provided with insulations so that they do not short-circuit the two rails. Fig. 158 shows some insulated fittings. What insulated fishplates are required depends on the protection desired. If the track circuit is only required on the straight track, the arrangement shown in fig. 159 is sufficient, as this merely provides insulation on the siding rails to isolate the circuit from adjacent lines. If, however, it is required to extend the track circuit so as to indicate when a vehicle is foul of the main track when on the spur line, then there are several schemes which can be applied. The one illustrated in fig. 160 is the simplest, but it depends on the integrity of the wires *x* (generally called "jumpers") for its reliable operation, as these connect the outer rail of the turnout to the main track. They ought therefore to be always in duplicate. A better plan is to employ the series arrangement shown in fig. 161, in which the rail in the main track is interrupted, and the current made to pass by way of the rail in the turnout. There are other ways of carrying out the same idea. At complicated junctions and cross-overs it is sometimes very difficult to get a satisfactory lay-out, especially where several track circuits adjoin and the dividing points are required to be in definite positions. These difficulties are rendered greater where bull-headed rails are in use, owing to the rail chairs butting together in narrow clearances.

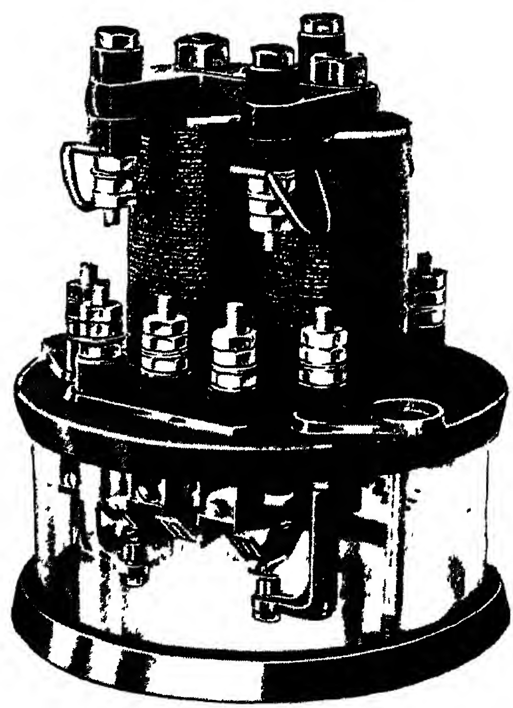


Fig. 162.—G. E. C. Direct-current Neutral Track Relay

Constituent Parts of Track Circuit: Track Relays.—The track relay is the most important element of every track circuit. Fig. 162 is an illustration of a modern type. It must be made of the best materials and in the best manner, as the whole security depends on its working properly. It must, when once set, operate without any appreciable change at the current values decided upon. The contacts must be large enough to carry the current required in the local circuit and not be liable to fuse together from any cause, such as lightning. Relays may be provided with a number of contacts closed either when energized (known as front contacts) or de-energized (known as back contacts). These contacts are operated whatever the polarity of the energizing current, but some relays are equipped with an additional armature which is moved to one side or the other, and closes corresponding contacts, according to the direction of the current in the coils. Relays so equipped are called polarized track relays, to distinguish them from neutral track relays.

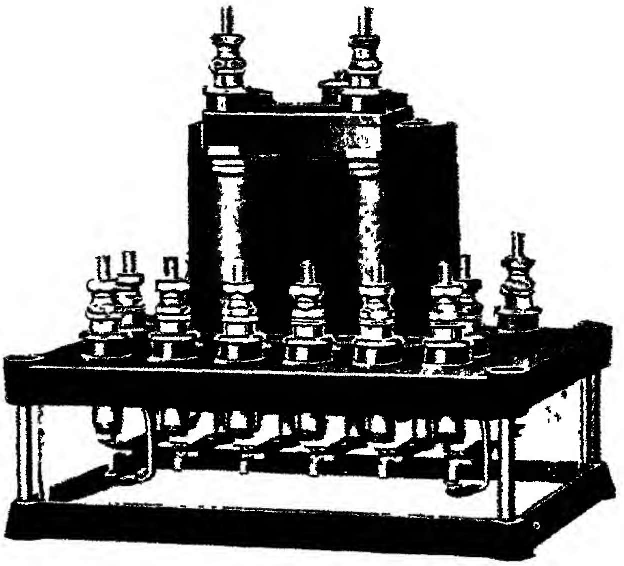


Fig. 163.—6 Front and 2 Back Contacts, Track Relay

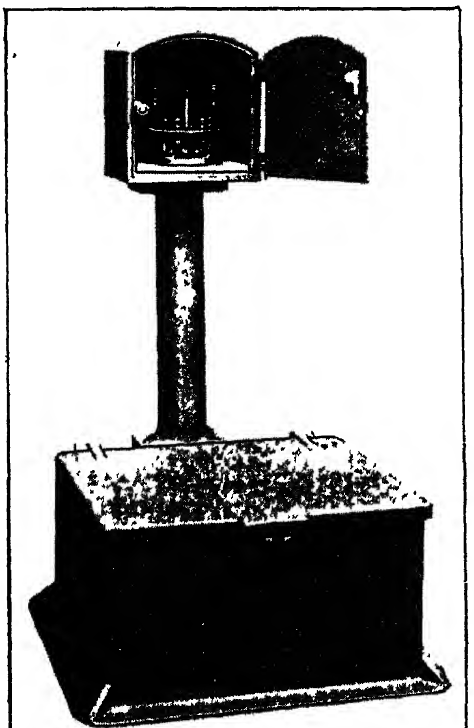


Fig. 164.—Track Relay Case

Another representative example of a neutral track relay, designed to the American Railway Signal Association specifications, is shown in fig. 163. It is made by the British Power Railway Signal Company.

Track relays have resistances of 1, 4, and 9 ohms as the case may be. The 4- and 9-ohm relays are popular for low-voltage accumulator-fed track circuits on open steam railways.

The pick-up current is approximately 40 m.a., and the release 25 m.a. for the 9-ohm type.

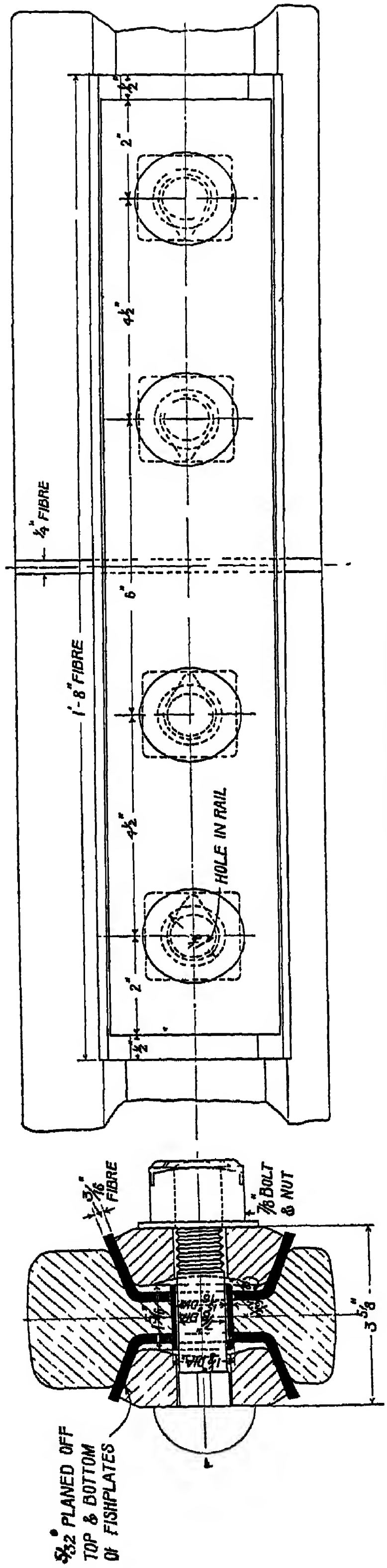


Fig. 165.—Simple Insulated Fishplate

The number of contacts provided depends on the duty of the relay.

The contacts themselves are either silver to graphite or morganite, or silver to silver, for ordinary control currents. When electric lighting or power current has to be handled, special contacts of suitable design are fitted.

It is of the greatest importance that relays should never stick due to a defect. To ensure reliability the armature and contacts are enclosed in a sealed glass-surrounded chamber, which enables them to be seen, but prevents tampering and damp and dust, &c., getting to them.

Another requirement is that the power required to operate them should be as small as possible, particularly for those which are constantly in circuit. The increase of a few milli-amperes results in a surprising addition to the cost of supplying power.

Track Relay Cases.—Wooden relay cases, sometimes zinc-covered, are used for housing relays alongside the track, but cast-iron containers are in favour at the present time, and present a neat appearance (fig. 164). A well for holding the batteries for the local circuit is provided at the base of the pillar, this being sunk in the ground. At cut sections this well contains the track batteries for the adjacent circuit.

Insulated Fishplates and Joints.—The simplest insulated joint is a block of very hard wood, such as hornbeam, used in place of the ordinary fishplates, and though used on the Continent on

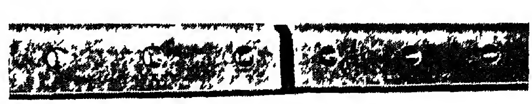


Fig 166.—Sykes' Rolled Section Flange Joint

main tracks is not seen in Great Britain except occasionally in sidings. Fig. 165 shows a method of insulating ordinary fishplates which is much

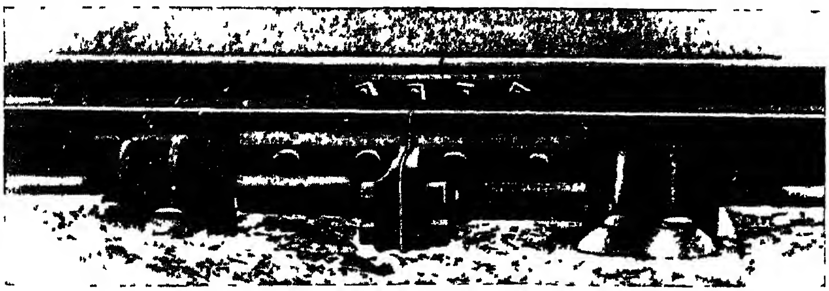


Fig. 167 —Sykes' Flange Insulated Rail Joint

employed, plates and collets of hard compressed fibre being used to separate the various parts electrically. Another form, in which the insulations are protected by a metal shield, designed by Messrs. Sykes, is shown in fig. 166, and has been much employed for flat-bottomed rails. Fig. 167 illustrates the Sykes flange joint which has been used extensively, and does not require any insulating material between the plates and the rails, with the result that the fibre lasts a long time, and the joint is easily kept tight.

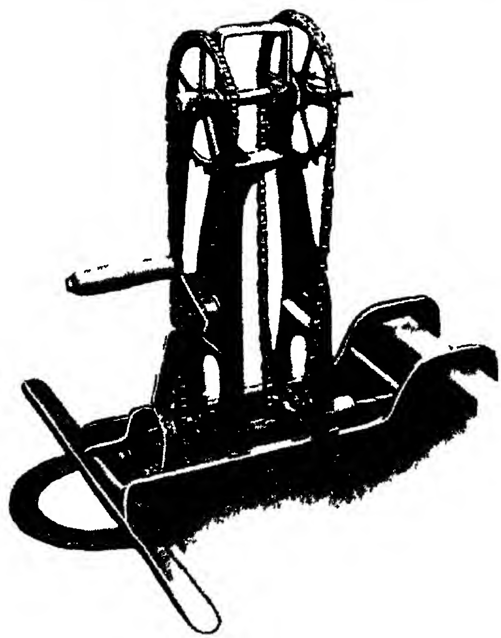


Fig 168.—Drilling Machine

Rail Bonds.—These are usually made by drilling the rail with the machine seen in fig. 168, and affixing galvanized iron or copper wires by driving in special taper pins called channel pins, which force the wire into tight metallic contact with the rail. It is best to fix two wires at each joint (fig. 169) to avoid risk of failure. The safe and economical working of a track circuit is much improved by good bonding; for

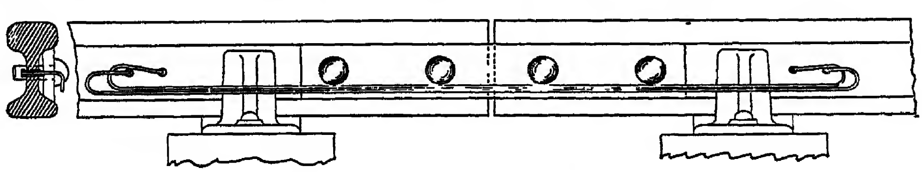


Fig 169 —Method of Bonding Rails

this reason heavy copper bonds gas-welded to the rails have lately been introduced in America.

Wheel Bonds.—Where Mansell disc wheels are used it is necessary to bond these to establish a connection between the tyre and the hub. One or more spot welds should also be made between the tyre and the disc of the wheel in all cases, as experience shows that the conductivity at this point is poor, due to a chemical produced when the tyre is shrunk on.

Track Batteries.—Track circuits were at first always operated by gravity batteries, a form of Daniell copper-sulphate cell, as these were capable of giving a continuous discharge without polarizing and had a comparatively high internal resistance, rendering it unnecessary to employ an external resistance to prevent excessive flow of current when the track circuit was occupied. Gravity cells, however, require rather frequent attention or else their working becomes erratic, which is particularly objectionable in track-circuit work, and they are also liable to freeze. Of recent years the gravity cell, though still extensively used, has been superseded by other primary batteries, and in some cases by secondary cells. The caustic-soda cell, on the market in many forms derived from the original Lalande cell, is much favoured by some railways. One type of cell is shown in fig. 170. The internal resistance is low, as is also the voltage, and an external resistance must be used to prevent heavy short-circuit currents. Caustic-soda cells require practically no attention, beyond watching to observe signs of approaching exhaustion and renewing in proper time. Leclanché cells are used quite extensively in France for track-circuit work, where caustic-soda cells are disliked owing to the danger of burning the hands with the solution, a number being coupled up in parallel for each circuit. In this way fairly good operation is obtained in spite of the unsuitability of the ordinary Leclanché cell to closed-circuit work. A modification of the Leclanché cell known as the A.D. cell has lately been introduced which is specially designed for closed-circuit work, and, it is claimed, does not polarize at all. This is also employed in France a good deal.

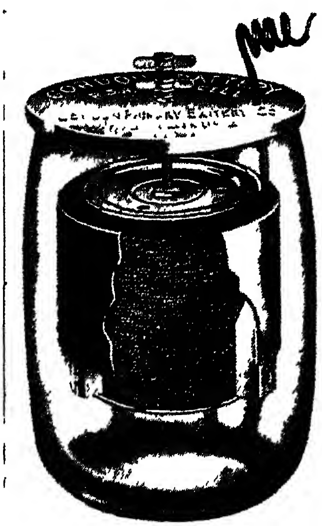


Fig. 170 —Soda Cell

One large railway in England uses portable accumulators for feeding track circuits. Their capacity is 1 amp. for 100 hr., and the average voltage 2. The cases are of stout celluloid, and the cells are carried in metal carriers with strap handles.

In order to get reliability the accumulators are changed for a freshly charged cell at definite intervals, usually every 14 days, although with some track circuits with poor ballast insulation they have to be replaced weekly.

When large numbers of accumulators are in use, and the charging and distribution are well organized, this is the least expensive way of providing

power for track circuits requiring 120 milli-amp. or more, from separate cells.

Regulating Resistance.—Even when not absolutely necessary, as

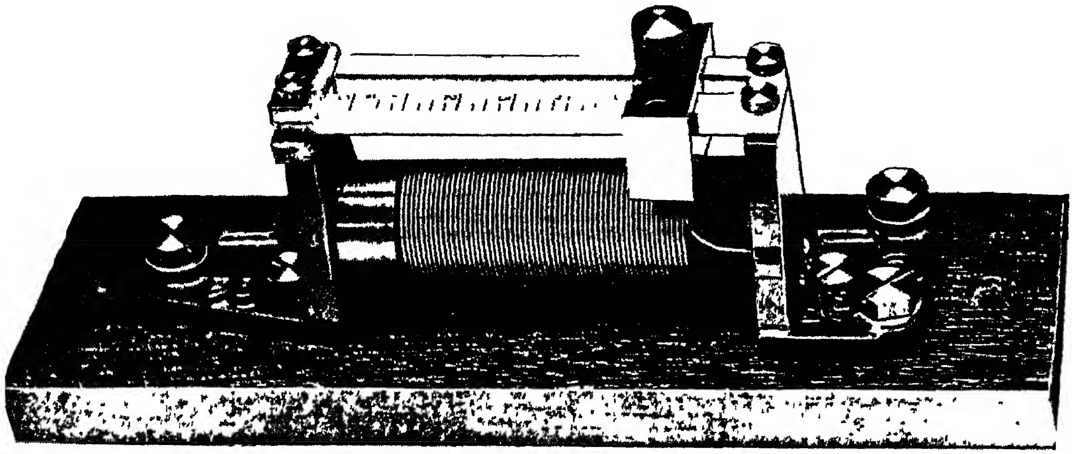


Fig 171.—Regulating Resistance

with gravity cells, a resistance in series with the track-battery feed is very useful, enabling a certain degree of regulation to be obtained, and the circuit to be worked efficiently. Fig. 171 shows a type of regulating resistance.

Automatic Resistance.—Even under the most favourable circumstances the current flowing when the track is occupied is considerable, and represents an entire waste of energy as there is no apparatus being usefully operated by it. To overcome this, automatic resistances have been introduced, designed to prevent any great increase in the current when the track circuit is occupied. One pattern, known as the thermal regulator, consists of an exhausted bulb, resembling an electric lamp, containing a filament of special material which increases considerably in resistance when heated and thus prevents any excessive flow of current from the track battery. Another device called the economizer (fig. 172) operates on the relay principle, and brings additional resistance into the battery feed as soon as the track is short-circuited, the current being then less than when the track is clear. These devices aid in improving the shunting properties of the circuit

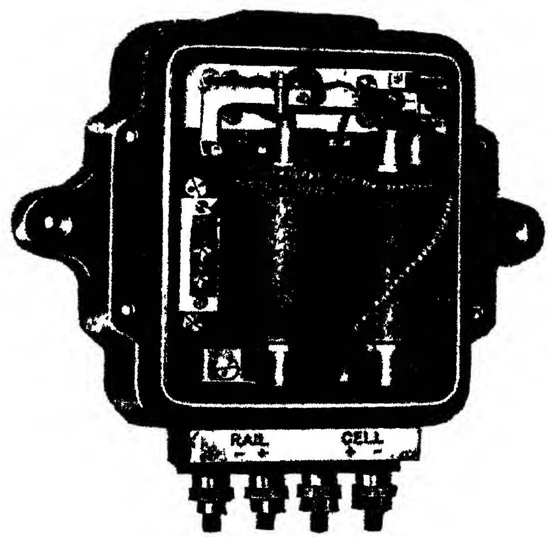


Fig. 172.—Track Economizer

as well as avoiding unnecessary expenditure of battery power. For track circuits which are occupied for many hours on end, such as platform roads where vehicles stand at night, they are very useful. Another arrangement employed to economize battery power is the "transient" track circuit, which is described later.

Connections to Rails.—These may be arranged in several ways and run in trunking or piping, &c. The best practice is to provide well-insulated cables of ample size to avoid any undue voltage drop, which should be connected to the rail with a flexible form of connection to allow for vibration, and take up any inequalities that may arise due to the track shifting. As the insulation resistance of a track circuit is poor at its best, some companies, notably in France, provide bare wire connections laid on the sleepers and held by clips, on the grounds that the further lowering of the insulation resistance amounts to very little compared with the total loss. This, of course, is a very cheap method of making the rail connections. On the other hand it certainly seems better, if the insulation resistance is already low, to try and keep it from getting worse, and this is the view generally followed. Where points and crossings are involved a considerable amount of rail connection work has often to be carried out. As far as possible standard methods of connecting up should be laid down and adhered to everywhere in such cases, and plans kept of all connections run underground to facilitate testing.

Electrical Features.—As a track circuit is operated by being shunted by the train, every care should be taken to get as low a value as possible for the shunt itself. In the ordinary way there is no particular difficulty in doing this with engines and complete trains, where the rails are bright. Sometimes, however, a single vehicle gives a poor shunt, if it has been standing in a siding and is not fitted with continuous brakes, a kind of scale forming on the wheels which is a bad conductor, and therefore it is equally necessary to regulate the circuit so that as high a shunt effect can be obtained as possible. Up to certain limits this can be done by increasing the voltage of the battery and using a corresponding regulating resistance. In spite of this there are places where heavy sanding may occur, or, owing to intermittent traffic, as for instance in and out of an industrial siding, the rails may become rusty, and in such circumstances it is not safe to rely entirely on the track circuit, but advisable to supplement it by using electric fouling bars.[1] This is a useful precaution close to buffer stops in terminal stations, and at those signals where drivers are likely to throw out sand in starting away with heavy trains and isolated vehicles are liable to stand at times where the sanding occurs. At stations where single vehicles are detached, such as horse-boxes, it is a very useful precaution to install detached vehicle indicators[2] combined with the track-circuit and have these operated by the platform inspector when a vehicle is detached in order to guard against any possible failure of the circuit. This has been done at several large stations.

[1] See Chapter XV, p. 234 [2] See p. 238.

Ballast.—The insulation resistance of a track circuit depends almost entirely on the nature and condition of the ballast, and to obtain the best

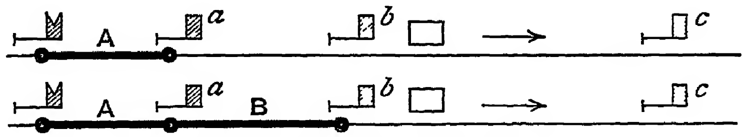


Fig. 173—Track Circuit at Home Signals

results it is essential to have a well drained and well ballasted track. The permanent-way department should co-operate with the signal department

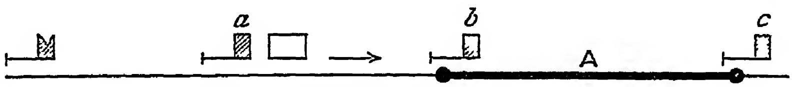


Fig. 174—Track Circuit at Advance Signal

in this important matter. What is particularly necessary is to obtain a constant insulation resistance, even if it be low, as the dangers arise when wide variations occur in the state of the ballast from time to time, making

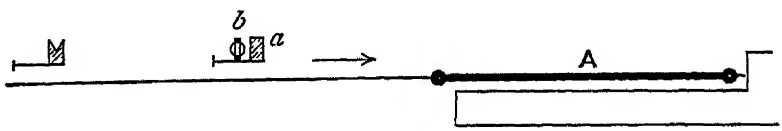


Fig 175—Track Circuit in Terminal Platform

it difficult to regulate the track circuit to meet them. Where there is excessively low ballast resistance it becomes impossible to successfully and economically operate track circuits by primary batteries, and some other source of power, preferably alternating current, must be resorted to. There have been cases where battery circuits have proved quite unworkable, but alternating-current circuits have operated satisfactorily.

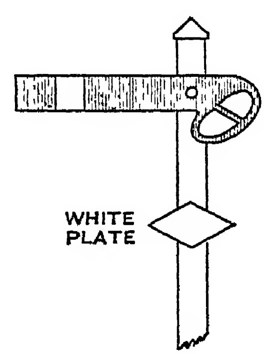


Fig 176.—Track Circuit Indicator Plate on Signal Post

Applications of Track Circuiting.—Track circuits may be employed in connection with all types of signalling, both power and manually operated. Automatic signalling, which forms one of its chief fields, is dealt with in Chapter X. In this chapter its application to other purposes will be considered.

Track Circuit with Manual Block Systems.—Track circuit is frequently laid down at signals which are at some distance from the cabin, and where in consequence there is likelihood of the presence of a train or engine being overlooked, and where it is difficult for the trainman responsible to proceed to the signal box to remind the signalman in accordance with rule No. 55. Fig. 173 shows applications of track circuit at outer and inner home signals. The circuit A would lock the block instrument for the section in the rear, while B would in addition lock the

outer home lever. Fig. 174 shows track circuit at an advance signal, and fig. 175 track circuit in a terminal platform line. In the latter case the home signal is provided with a calling-on or shunt arm to allow engines, &c., to proceed cautiously into the occupied track. This arm *b*

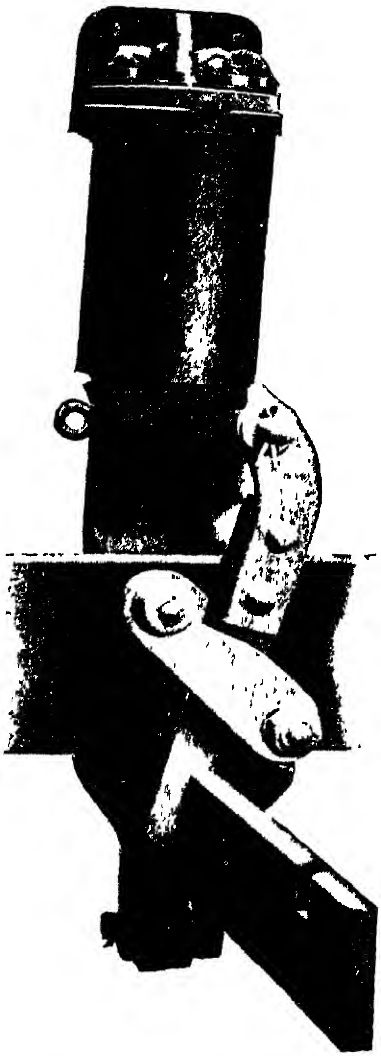


Fig. 177.—Electric Lever Lock

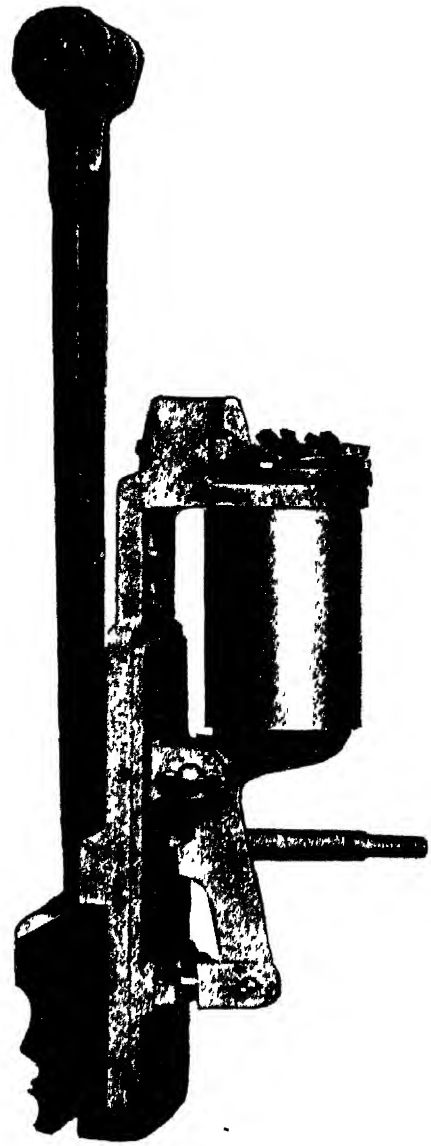


Fig. 178.—Vertical Tappet Lock

is always free, but *a* is locked when the track is obstructed. Both arms can be operated by one lever, if an electric selector (see p. 241) is used. At junctions and similar places the track circuit requires careful splitting up into sections in order to obtain the locking required, but this must be done in such a manner that permissible movements are not hampered in any way. Fouling or clearance protection should be given wherever trains can stand foul of another track, as far as possible, and

if this cannot be done without considerable complication in the track-circuit lay-out, it is better to make this simpler and supplement it by electric fouling bars.

Enginemen's Indicators.—Wherever track circuits are installed it is usual to exempt the trainmen from observing rule No. 55, and therefore they require to know at what signals the exemption is in force. For this purpose some railways provide indicator plates (fig. 176) fixed on the posts of such signals. Others go further and provide an illuminated sign by night showing " train indicator in box " or similar wording, while others content themselves with issuing to the staff a list of exempted signals. On some lines all signals are exempted on sections worked by the lock-and-block, and provided with indicator plates.

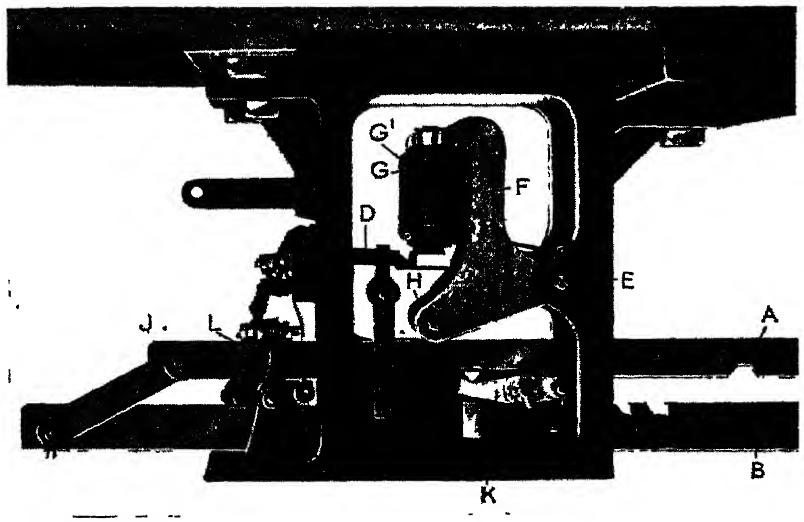


Fig 179.—Lever Lock, Type B.P.

Apparatus in Local Circuit.—There are several forms of electric lever lock, one of which is shown in fig. 177. It acts directly on a horizontal tappet attached to the lever, and is strong and easily fixed. Another form for vertical tappet is illustrated in fig. 178. This is more convenient in certain situations, as for example in narrow signal cabins.

Another type of lock, known as the B.P. positive lever lock, type L, is so designed that the armature is not lifted by the magnetic pull of the lock coils.

Fig. 179 shows the lock, which operates as follows. A is the top tappet connected to an extension of the catch handle and is linked as shown with the bottom tappet. B is the bottom tappet connected to the lever. C is the main locking dog which engages with suitable notches in the bottom tappet. The locking dog is carried by the horizontal armature arm D fulcrumed at E. F is a bracket fulcrumed at E, carrying magnet coils GG′ and roller H. When the catch handle is operated, it causes the top tappet

A to rise and come in contact with roller H, after which it raises bracket F and with it coils GG′.

If the coils are energized, viz. when the control circuits are in agreement, armature arm D will remain adhering to the pole tips and will be raised with the coils, so lifting the main locking dog out of the notch in the lever tappet B.

J is a current-saving switch which comes into operation immediately the top tappet lifts and completes the circuit through coils GG′ before the top tappet touches roller H.

K is a subsidiary locking dog to act as a stroke-completion compelling device.

L is a contactor which makes contact normally and is broken by the lifting of the catch handle. It can be used for lock detection.

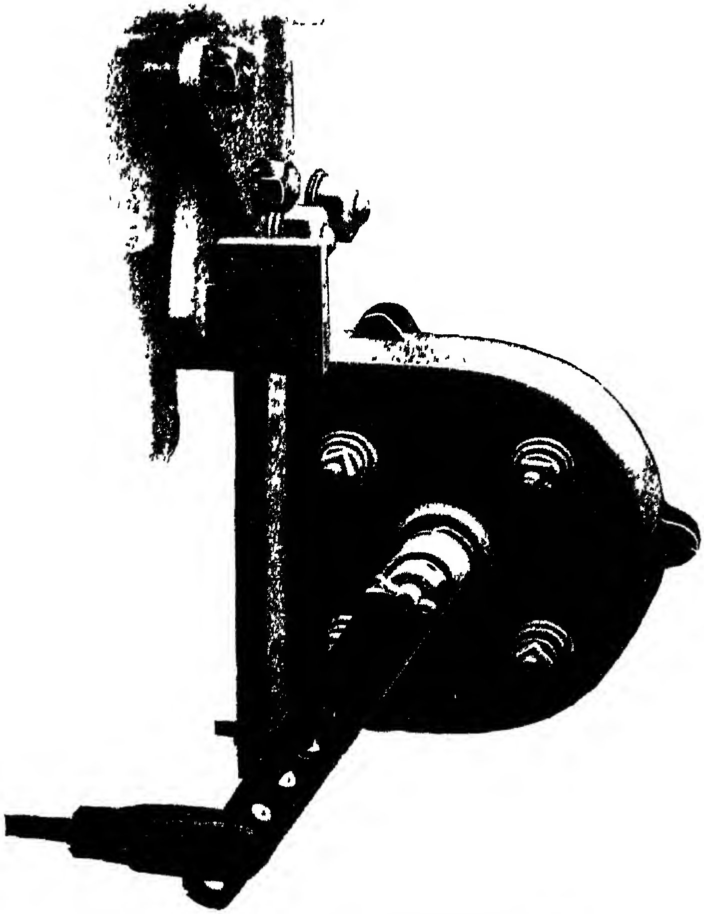


Fig. 180.—" D " Pattern Lever Contact Box

A hand plunger or trigger contact is used to close the circuit to the lock when required. Sometimes a foot contact is used. This is very convenient for point lever locks, which are often applied to the reversed position of the lever. Lever contact boxes are often required to control circuits in track locking schemes, and fig. 180 shows one form much used. Where block instruments are locked a simple form of electric lock on the handle or plunger is all that is necessary, a small push-button to control it being fixed to the instrument. Some companies interrupt the block circuit or make the occupation of the track hold the block needle at " train on line ", and do not provide any lock.

To indicate the state of the track to the signalman several kinds of indicator are in use. Figs. 181 and 182 illustrate a few. These are satisfactory unless the number of track circuits is considerable, when it is far

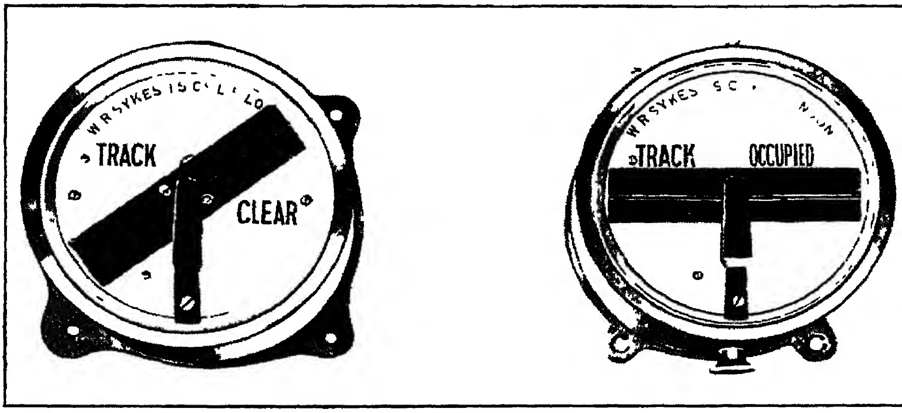


Fig. 181.—Track Indicator

better to adopt an illuminated or else a bull's-eye track diagram. Fig. 183 shows one of the former. Each track section is illuminated by lamps carried in compartments behind the diagram controlled either by the track relays or more usually their line relays. The lights are extinguished when the track is occupied. A simpler form, which has only one lamp on the centre of each section, is often used in the smaller installations. The eye-ball diagram (fig. 184) has red and white indicating flags showing through holes cut in the diagram, one being placed in the centre or at each end of every section. The red indication shows the track is occupied. It is good practice to combine, in the one diagram, platform starting or destination indications when these are in use, and the diagram is large enough to allow this to be done. A buzzer is sometimes provided in conjunction with track indicators, arranged to sound when the line is occupied, especially at outer home signals. If a track is likely to be much occupied buzzers are rather objectionable, and instead a single-stroke bell may be used which gives one beat directly a train comes on the track circuit.

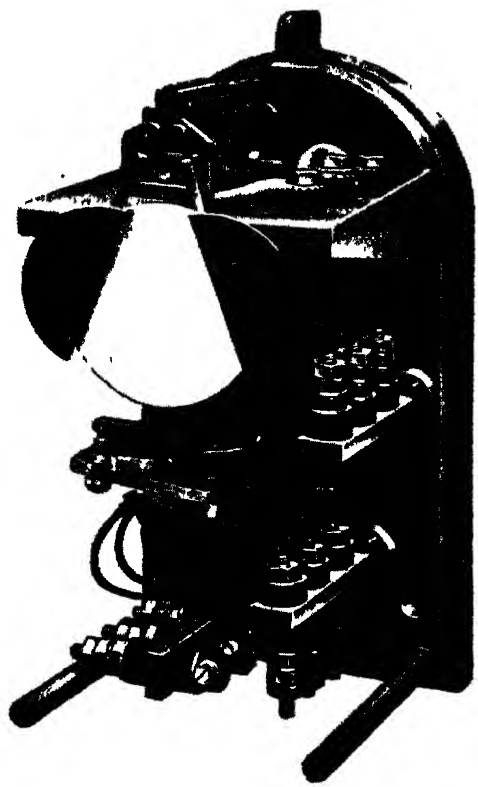


Fig. 182.—Track Indicator with Relay Movement

Automatic Replacement of Signals.—It increases the safety very

much at many places (and at some is indispensable to it) if a signal is placed to danger automatically when the relative track circuit is occupied This is accomplished by employing an electric[1] signal replacer or reverser (fig 185), which causes the arm to assume the stop position, while the lever in the cabin is still reversed, directly the current is cut off the controlling coil Another type of reverser is seen in fig 186, while there is also one, known as the rotary slot, which is fixed directly on the spindle of the arm itself When the signal is thrown to danger by the reverser, the lever must be put back and pulled again in order to lower it The electric lock how-

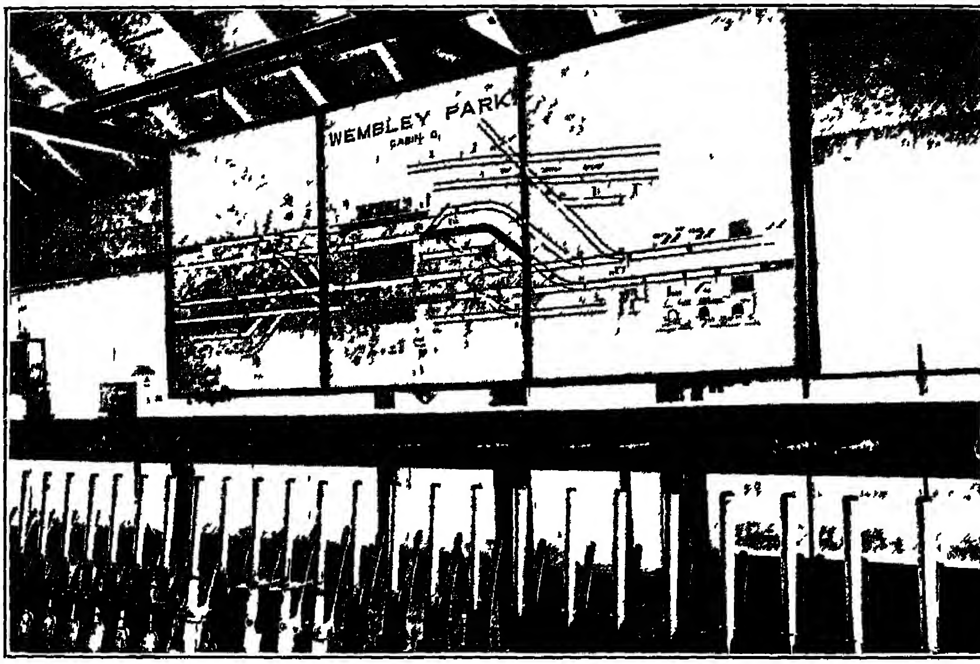


Fig 183 —Illuminated Track Diagram

ever, prevents this while the track is occupied Reversers are also operated by treadles for other purposes, especially with lock-and-block systems, and are sometimes used to realize slotting between two signal boxes where mechanical slotting would be complicated and unreliable Instead of mounting them on the signal post some companies have fixed them under the signal cabin, adapted to release the signal wire when the control is cut off Theoretically this is not good practice, as the mere releasing of the wire is no guarantee of the movement of the signal arm, but there is an advantage in this method in that it permits of one reverser being applied to several signals leading on to one track circuit

Route Locking.—Track circuit enables the approach of a train to control points ahead of it for a given distance, so as to prevent any dangerous change of route being made, thus completing the principle contained in

[1] There are also mechanical reversers, see p 36

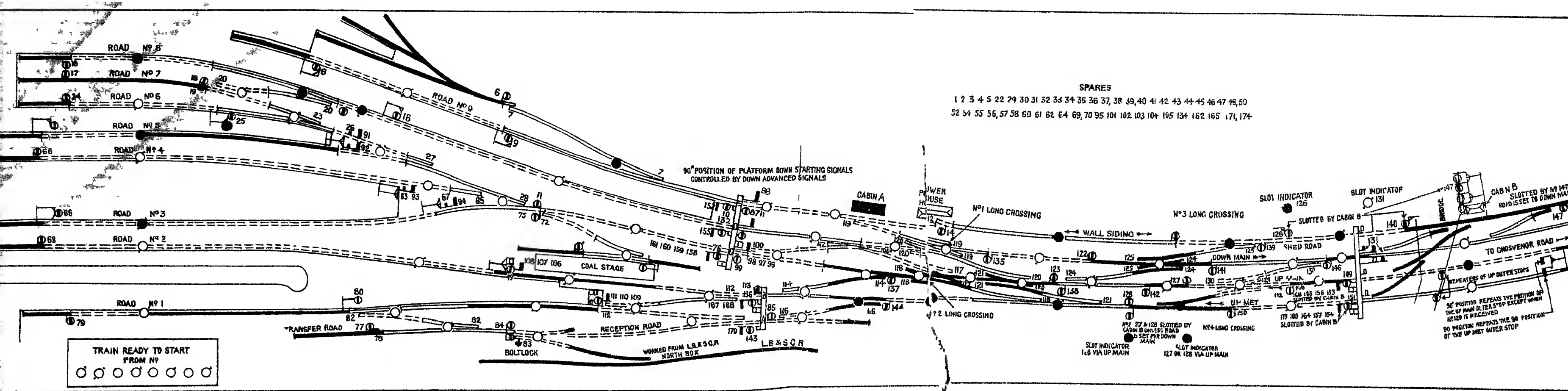


Fig 184—EYE-BALL TRAIN DIAGRAM

[Facing p 132

points interlocking in lock-and-block working This has been developed to a remarkable extent and very thoroughly applied to some modern power interlockings, but space only permits of a brief mention of it here Fig 187 shows a simple case, in which route locking is obtained through back-locking When either signal *a* or signal *b* is cleared with track A occupied, the lever becomes back-locked, that is it can be replaced far enough to put the signal to stop, if required, but not far enough to release the mechanical locking on the facing points *x*, so that the route cannot be changed in the face of the train Where this control is provided mechanical F P L bars are not required, and have been dispensed with in many cases If the signals govern more than one pair of points they will all be held as long as the lever cannot be fully replaced to normal, but the provision of one track circuit only in the rear of the signal post is obviously not sufficient to control a series of points in this way

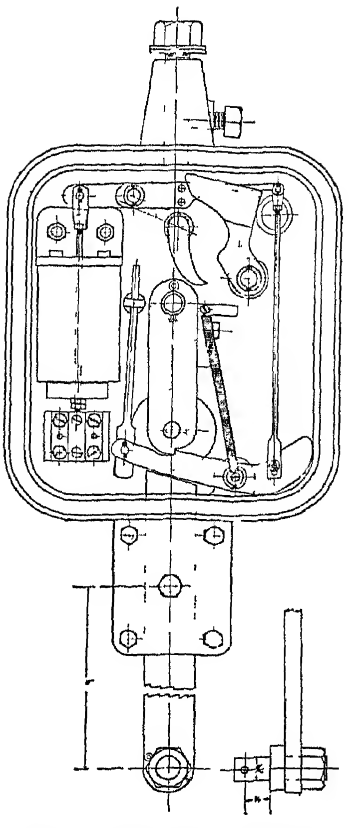


Fig 185 —Sykes' Electric Reverser

Fig 186 —Westinghouse Electric Signal Reverser

Sectional Route Locking —The principle of this may be understood by referring to fig 188, in which the two signals *x* and *y*, fitted with route indicators, lead to several different tracks, A to F, through switches *a*, *b*, *c*, *d*, and *e*, from two tracks I and II Imagine signal *y* cleared for a movement from II to A It would be back-locked by a track circuit in the rear of it, as already described In addition to this a track circuit would be laid down ahead of the signals, and split up into sections covering the various switches, and the fouling points between the different lines at them Directly the train passes signal *y* it electrically locks the whole of the points in the route, in this case *aa*, *b*, and *e*,

independently of the mechanical locking, so that should *y* be replaced after the train has passed it the route is still held When the train, however, passes clear of *aa* these points are released and may be changed, and the same with *b*, allowing *x* to be cleared for a movement from I to D at the earliest possible moment, leaving *e* locked for the first movement till the train clears it At large terminal stations locking of this kind gives a very high degree of security, and reduces the number of signals required to a minimum, while allowing full freedom of movement

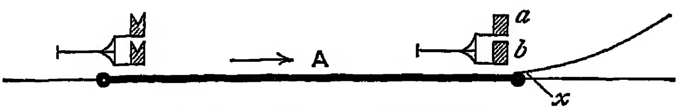


Fig 187—Track Circuit as Route Lock

It can be made applicable to movements in both directions over the same route

Back-locking of Shunt Signals—This adds greatly to the security of shunting movements, but cannot be carried out as shown in fig 187, as if vehicles are left behind on the track, which would often occur in shunting, the signal lever could not be replaced A special circuit is therefore employed which brings the route locking into action for each movement, but allows the restoration of the lever notwithstanding that the track in the rear of the signal is still occupied The lever must be replaced and pulled again to clear the shunt signal for each movement

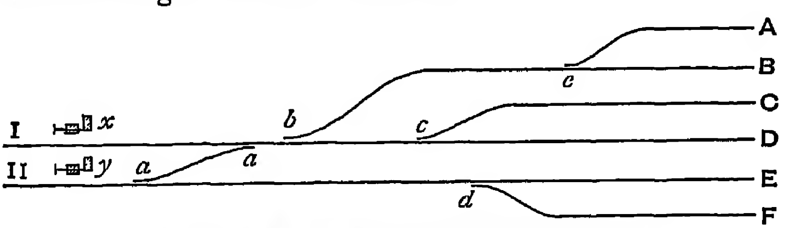


Fig 188—Illustrating Principle of Sectional Route Locking

Semi-automatic Control of Signals—At power interlockings the automatic replacement of signals to danger is carried out by interrupting the control circuits, but if this is all that is provided, the signals assume the clear position again directly the track concerned is clear if the signalman does not move his lever This is sometimes unsatisfactory, especially at a facing junction, as it may lead to a signal being cleared for a route not intended, and the train may start and proceed on this route at once by mistake To prevent this it is customary to make it necessary to replace the lever and pull it again before a signal, that has been restored to danger by a previous train, can clear This is sometimes called "stick" control of signals, as it is realized by using a stick relay

Stick Relay—The principle of this is illustrated in fig 189 It enables a certain condition of control or locking, &c, to be established at one

moment, and held until the time comes for releasing it It is employed in very many different circuit schemes at the present day, these are too numerous to deal with here Instead of a single winding on the relay it is often better to employ two, one of low resistance on the pick-up circuit and one of high resistance in the retaining or "stick" circuit

Track Circuits operated by Central Battery —Where there is a group of track circuits near a reliable source of electricity supply, it is economical to install a central accumulator battery of 150 to 200 amp -hr at 6 or even 24 volts The battery should be in duplicate so that one can be recharged while the other is at work A pair of feed cables run amongst the group of track circuits and tappings through series feed resistances are made to the rails By this method the necessity for replenishing primary cells or changing discharged portable accumulators is dispensed with

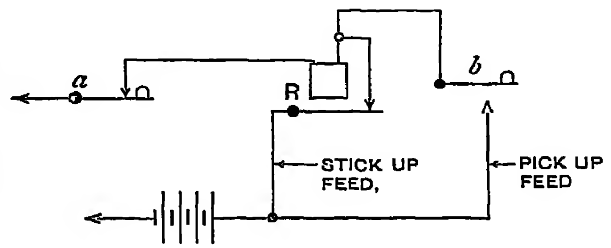


Fig 189 —Principle of Stick Relay

Pressing key *a* releases relay R which cannot be energized again until key *b* is depressed

Intermediate Block Signalling —There are many signal cabins which serve simply as section posts between stations, and are provided to shorten the block sections If automatic or semi-automatic signalling can be introduced in place of them, such signal cabins can be closed altogether, and considerable economies can be realized There is also the additional advantage that there is no need to open a cabin for a short period to cope with additional trains Track circuiting provides a ready means whereby the signals originally operated by the intermediate post can be controlled with perfect safety from the cabins at the stations on each side Fig 190 shows one way of doing this The intermediate block signal *a* is provided

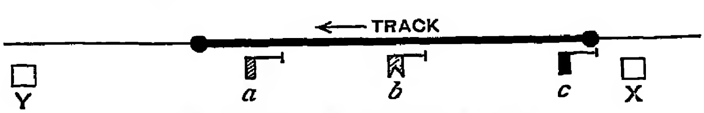


Fig 190 —Intermediate Block Signalling

with a distant signal *b*, just as if it were worked from an independent signal box, but it is actually worked electrically from cabin X as an advance signal Track circuit is laid down from the last mechanical signal, *c*, at X to a point about 440 yd beyond *a*, to control the admission of trains to the section *ca* Block working is maintained to control the section from *a* to cabin Y, or better still, lock-and-block may be installed A telephone is usually fixed at the intermediate signal so that trainmen, if necessary, can ascertain why they are being held there The number of actual track circuits required varies according to the distance and other local circumstances An alternative method is to operate the intermediate signal from

Y as an outer home signal and dispense with block working, but this method is not so much favoured as the one described. Some companies provide repeating block instruments in a case fixed on the signal *a*, so that the block indications can always be seen by the trainmen.

Transient Track Circuit[1]—This has been developed principally in connection with intermediate block signalling, the object being two-fold, to economize battery power and to extend the limits to which a single track circuit can be worked, thus eliminating cut sections. In the closed track circuit hitherto described the battery, or other source of energy, is always delivering power to the circuit, even when it is clear, and unless controlled by a thermal or other automatic regulator, this amounts to a considerable figure when the track is occupied. Little or no purpose is served by this constant expenditure of energy, and in the transient track circuit, which has been developed by the Automatic Telephone Manufacturing Company, Liverpool, power is only supplied to the track circuit just before the signal leading on to it is pulled off, or in other words only when it is required to test whether it is clear or occupied. This is not done by switching on the track battery directly (a method adopted at a few places for some time), but special apparatus is provided which converts the continuous current delivered by the battery into a pulsating current which operates the track testing lock, enabling the signal to be cleared, only when a certain definite number of impulses have been transmitted. As the track relay is normally de-energized, the shunt obtained is higher than with the ordinary normally energized relay, while much longer track circuits can, it is claimed, be installed. As the indicator in the cabin cannot be worked in the ordinary way and give a continuous indication, which is usually considered necessary, it is controlled by a special circuit through separate insulated rail lengths placed at each end of the section. When the signalman proceeds to obtain his lever lock the indicator changes to "occupied", and resumes the "clear" position when the series of impulses transmitted over the track proves that it is clear. A vehicle passing on to the first "indicator rail" places it at "occupied", while in passing over the second one it indicates that it is clear, provided the track is actually clear. This action takes place whatever the direction of movement may be—vehicles may come on the track and leave it at either end. These indicator rails may be dispensed with if a continuous indication of the state of the track is not required. The transient system has been developed also for single-line working, to form a track-circuited lock-and-block which can be used without staff or tablet. It has only comparatively recently made its appearance, except for isolated attempts in London and in Belgium, but is attracting considerable attention on account of the economies it promises to effect in intermediate block signalling installations. Both in such installations and in conjunction with ordinary block working track-circuiting, whether working on the transient or on the ordinary principles, has already enabled many signal cabins to be closed.

[1] See also p. 142

Interference by Stray Currents —At certain localities trouble is often experienced through earth currents interfering with the operation of track circuits, as, for instance, in the neighbourhood of electric tramways Unless the source of disturbance can be removed it may be necessary to employ alternating-current track circuits in place of battery-fed circuits, as these can be so arranged as to be immune to foreign currents Special devices have been invented designed to protect battery-fed circuits from outside influence, but it cannot be said that any have proved really satisfactory as yet

Track-circuiting on Electric Railways —The danger of interference on electric railways is necessarily very great owing to the heavy traction currents flowing near the track rails, where an insulated traction circuit is employed, or in them where, as is mostly the case, the running rails themselves form part of that circuit This is particularly so in direct-current traction systems on suburban lines where the voltage is not high On high-tension alternating-current railways battery-operated circuits, with single insulated rail, have been successfully operated, provided the traction return rail is heavily bonded to an earthed cable, but on direct-current traction systems this method is out of the question The most modern practice is to employ alternating-current track-circuits, but before these were designed, Brown's polarized relay system, fed from a direct-current main supply, was much used, especially on the London Underground Railways

Brown's System —This is illustrated in fig 191, but is now being replaced by A C track circuits On the London lines the traction circuit is completely insulated, but the system may also be used in those cases where the running rails form the traction return circuit, and it has been applied on the Boston Elevated Railway in this manner.

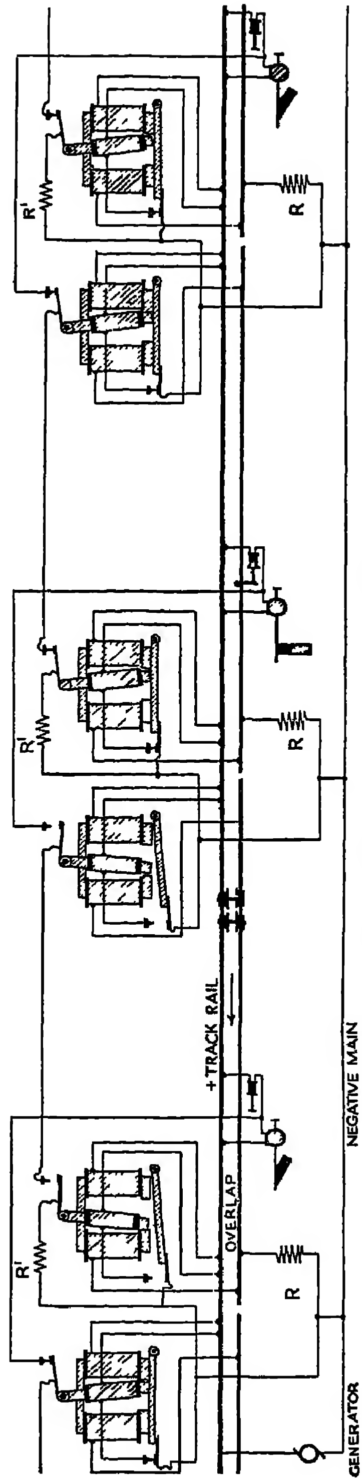


Fig 191 —Direct-current Polarized Circuits, London Underground Railways

One of the running rails forms the positive conductor from the supply to the individual track sections The other running rail is insulated at the ends of the block sections in the usual way, all the intermediate rail joints being bonded Resistances are inserted in the connections between the negative main—which are always at the latter end of the block section—and the insulated rail, these resistances reduce the current to between 2 and 4 volts, according to the length of the block and the local conditions

The positive current flows along the continuous rail, through the track coils of the two relays, one at each end of the block, to the insulated rail, and thence through the resistance to the negative main It should be mentioned that a portion of the current flows from rail to rail through the ballast Suspended from a pivot between the pole pieces of the relay is a swinging coil which is wound to a high resistance and is connected between the positive rail and the negative main through a contact, the latter being closed by the track-coil armature when the track coils are energized

The signal circuit controlling the motors passes through the contact which is closed by the swinging coil of both relays in series As soon as a train enters the block section the relays are short-circuited by the wheels, and, being de-energized, their armatures drop, thus breaking the circuit through the swinging coil The latter then falls away from its pole piece, thereby breaking the top contact As both relays act in sympathy the signal circuit is therefore broken at two points, causing the electromagnet of the signal motor to be de-energized and the signal to return to danger by gravity

How far the stray-current difficulty has been met will be understood by the following conditions, which may occur with a train in the section

1 Both relays shunted, no extraneous current (normal)
2 One relay shunted, the other energized normally (signal circuit broken at one point)
3 One relay shunted, the other energized reversely (signal circuit broken at two points)
4 Both relays energized, one normally and one reversely (signal circuit broken at one point)

The signal circuit is therefore always broken at one point, and often at two, when a train is in the section

The relays and resistances are housed in cast-iron boxes, which are fixed to the side of the tunnels or carried on short posts fixed in the ground

II —ALTERNATING CURRENT

Alternating-current Track Circuits.—When direct current is present in the running rails, which condition arises with certain systems of electric traction, and also due to earth leakages in or near large towns, it is necessary to resort to the use of alternating current for track-circuiting purposes

The controls which can be provided remain the same The difference

is in the power-feed arrangements and the type of relay employed

The feed is generally from a low-tension transformer giving 6 volts, and thence through a feed resistance of some kind, to the rails The current taken varies, but is much more than with direct-current battery-fed track circuits With some alternating-current track circuits as much as 5 amp may have to be fed to the rails

A recent and interesting development is the system of feeding the track circuits straight from the 100-volt supply through static condensers to the running rails This system has been developed because the static condenser will not pass direct current, and therefore any short circuits from the traction system cannot find a path through the transformer secondary winding

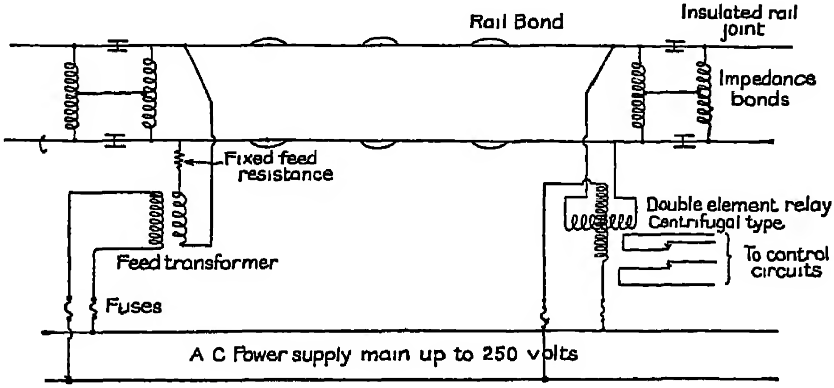


Fig 192 —Alternating-current Track Circuit Double Rail

On some electric railways the presence of the insulated rail joints would interrupt the flow of the return traction current To overcome this, the insulated joints are bridged by impedance bonds, which are so designed that the heavy direct-current traction current can pass freely from the trains to the power house, as the impedance bonds have only a small ohmic resistance However, their impedance to alternating current is sufficiently high for it to be possible to maintain an alternating-current potential between the rails of any one track circuit (see fig 192)

The relays used for alternating-current work are of four kinds, viz the vane type, galvanometer type, polyphase type, and the centrifugal type The vane and centrifugal types can be of the single- or double-element variety

A single-element relay has one winding only, which is connected to the rails and receives power from them The double-element relay has in addition to the winding connected to the rails another winding connected to the alternating-current power supply mains

The centrifugal and frequency vane types can be made to respond only to alternating current within a definite band of frequencies Thus with traction alternating current at frequency 25, the relay can be made to respond only to alternating current of frequency 60

By this means alternating-current track-circuiting can be used on railways employing alternating current for traction purposes, provided, of course, that the traction alternating current is of different frequency to the signalling current, as shown above An important advantage of alternating-current track-circuiting is that long lengths, up to 2 to 3 miles, of rail can be track-circuited without cut sections

The power question is not particularly important with alternating-current track-circuiting, as this system would not be installed if a power-supply system was not available Train shunt values equal to those obtained with the direct-current system, can be obtained

The different types of relay work as follows

Single-element Vane Relay—A pivoted segmental sheet of non-magnetic metal is supported on a stop between laminated iron pole pieces The pole pieces have one half of each tip enclosed by a copper shading ring

The magnetic system is excited by a winding obtaining alternating current from the rails When the alternating-current field is sufficiently strong, eddy currents are generated in the metal segment, and owing to the distorting effect of the copper shading rings on the magnetic field a lifting force is developed in the segment, causing it to lift against gravity

Suitable gearing causes this movement to make or break control contacts

Double-element Vane Relay—In this type the vane is slotted and moves between magnet poles, one set of which are excited by the alternating-current power supply called "local" coils, and the other by "track" coils which obtain the exciting current from the rails

The "local" and "track" currents should be as near as 90° out of phase to get the best turning effect on the slotted vane (fig 193)

The slotting of the vane causes the currents induced therein to pass as in a conductor at right angles through a magnetic field, and a turning force is developed in consequence

Polyphase Type—This is also a double-element relay There is a magnetic field system consisting of a "local" coil and a "track" coil mounted on iron pole pieces, and so arranged that the "track" coil current is 90° out of phase with that in the "local" coil A rotating magnetic field is therefore created amongst the pole tips

In this field is pivoted a drum or rotor of non-magnetic metal, which drum is geared by a pinion to a tooth segment moved between stops and against a controlling weight by the rotation of the rotor

The rotating field sets up eddy currents in the rotor and drags it round

Centrifugal Type.—These can be both single- or double-element pattern In this type, instead of the rotor being limited to a small number of revolutions, the rotor revolves at synchronous speed, provided both the "local" and "track" coils are excited

Attached to the spindle of the rotor are governor balls, so set that after a certain speed they fly open and move a sliding sleeve which causes control contacts to make or break as desired

With the double-element pattern, should stray alternating current

reach the " track " coils and be of different frequency or out of the correct phase, the rotor will not revolve at the speed sufficient to operate the contact mechanism

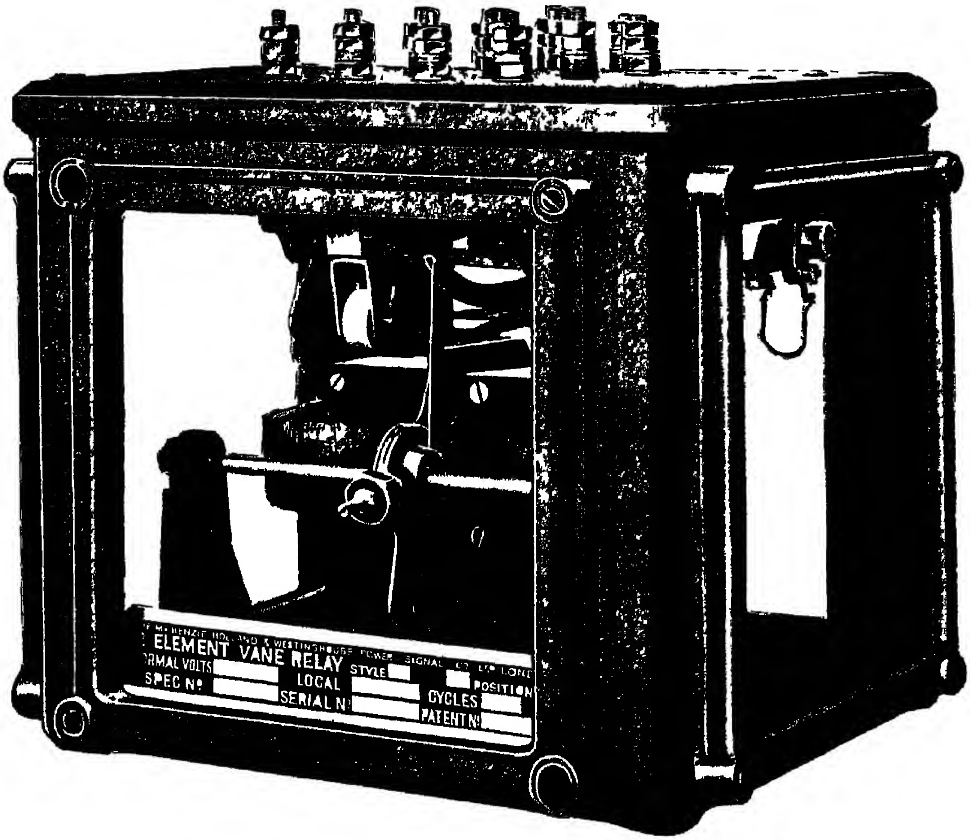


Fig 193 —Style G, Alternating-current Vane Relay, 2-Element, 2-Position

Some values for the power required to operate " pick up " alternating-current relays are shown below

Type	Current	Volts	Frequency
Vane (single element)	3	2	50
Vane (double element)	Track 0 25 Local 0 4	0 8 100	50
Galvanometer (double element)	Track 3 Local 0 6	1 25 100	60
Polyphase (double element)	Track 1 4 Local 0 3	1 7 100	50
Centrifugal (single element)	2 2	1 7	60
Centrifugal (double element)	Track 0 9 Local 0 3	0 9 110	60

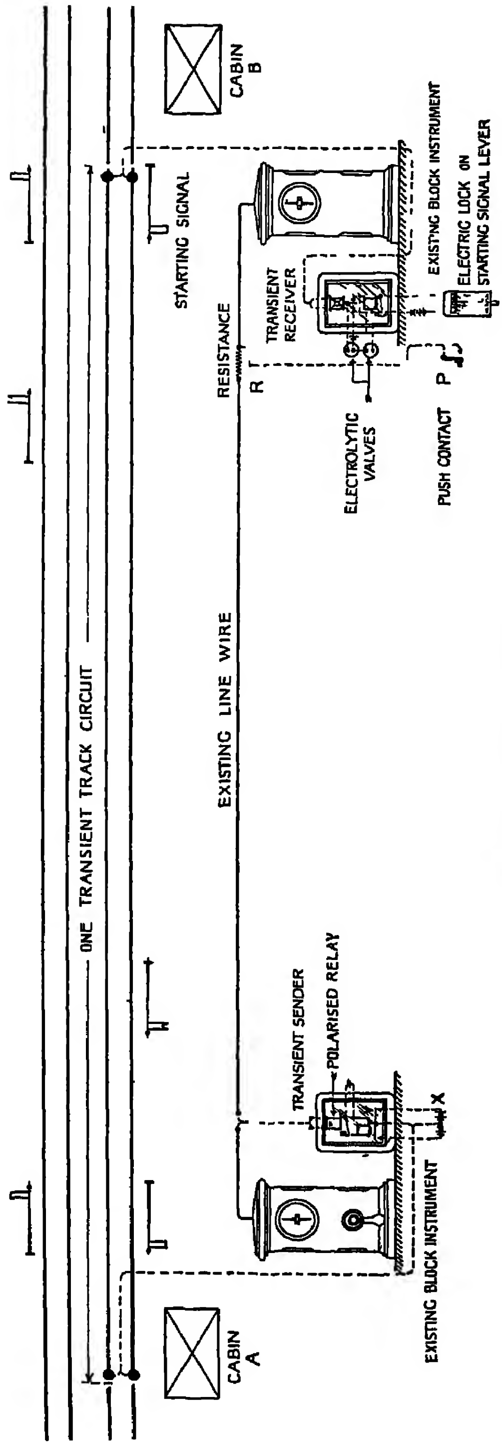


Fig 194—Transient Track Circuit

Transient Track Circuits.—A recent development in track-circuit systems for use on open main lines, is to apply the power to the rails only when the signalman requires to pull off the starting signal, and so prove that they are unoccupied It can also be arranged for the "line-clear" current to control the lock on the signal in the rear

The method of working this circuit, which is due to the Automatic Telephone Manufacturing Co, is as follows Fig 194 should be referred to

The starting-signal lever in cabin B is locked in its normal position by means of the electric lock shown Before a release of the starting-signal lever can be obtained, a "line-clear" indicator must be received from cabin A in advance, and to the rear of whose home signal the line is track-circuited

The block wire at cabin A passes through the coils of a polarized relay PR in the transient sender The "line-clear" current when applied to the block wire by the signalman at A, although of correct polarity, is too feeble to energize the polarized relay PR, owing to the presence of a line resistance R at cabin B

The line resistance R is so arranged that the current in the block wire, although sufficient for the correct operation of the block instrument indication, is inadequate for energizing the polarized relay PR The situation now is that "line clear" is showing at A and B

The signalman at B, wishing to pull off his starting signal, presses the

push contact P This short-circuits the line resistance R, and so increases the "line-clear" current sufficiently to pull up the armature of the polarized relay PR

The closing of this armature energizes the vibrator coil The vibrating reed V is set in motion, and alternating-current impulses from battery X sweep the track-circuited section of the running rails The rails being unoccupied, the transient receiver B responds to the impulses, and stores up energy by means of the electrolytic valves, which, discharging through the coils of the direct-current relay, closes a local battery circuit for the electric lock, releasing it for the few seconds required for the starting-signal lever to be pulled A lock indicator informs the signalman when the lock is "off"

It is claimed for this system that existing block circuits require no additional apparatus, and that the power required to operate the track circuit is only needed for about eight seconds per train

Should the block circuits fail for any reason, the track-circuit protection is still available No continuous indication of the state of the track circuit, viz "track clear" or "track occupied", is provided.

CHAPTER X

Automatic Block Signalling

To realize the idea of the block system by purely automatic apparatus and eliminate the signalman was proposed in the early days of railways, and patents were taken out for various proposals, most of which had little of practical value in them Track-circuiting was unknown, and before it was developed the only method of controlling automatic signals was by means of treadle contacts of some kind actuated by passing trains at intervals along the line There are still a few examples of this method, notably on the Paris Metropolitan Railway, but it is unlikely that they will find any imitators in the future

Intermittent Contact Systems—All such systems suffer from

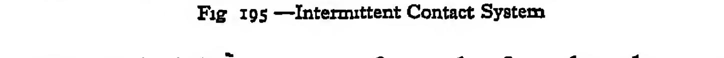


Fig 195—Intermittent Contact System

certain fundamental defects, arising from the fact that the control of the signals is not continuous, but is set and released at intervals Fig 195 serves to illustrate this In all automatic systems it is necessary to authorize a train to pass a signal at stop after waiting a certain interval in order to prevent a defective signal from causing a complete stoppage of traffic If we suppose in fig 195 that train I stops for a time in the section between signals *a* and *b* and then restarts, while train II has passed signal *a* at stop,

then train I in leaving the section and passing over rail contact C will clear *a* behind train II This is a very serious weakness of intermittent contact systems To overcome it, wheel-counting systems have been designed whereby the train in passing over contact A registers the number of wheels passing into the section, and similarly at contact C registers their passage out of it Although in some tunnels in Switzerland this arrangement has proved fairly satisfactory when combined with a good lock-and-block system, it cannot be regarded as in any way suitable for automatic signalling, where track circuiting, which gives positive, permanent control of the signals all the time the section is occupied, is the only satisfactory

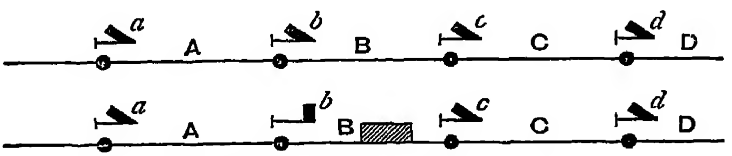


Fig 196 —Simple Automatic Block System

method that eliminates the difficulties referred to Before describing any circuits or apparatus, the principal automatic schemes in use will be reviewed from a traffic standpoint

Simple Automatic Signal System.—Fig 196 illustrates a very simple arrangement of automatic signals Each section, A, B, C, D, &c , is governed by a corresponding signal *a*, *b*, *c*, *d*, &c , which stands at clear when the line is unoccupied, and at stop when a train is in the section, as at B in the lower part of the figure The block sections may comprise several track-circuit sections worked on the relayed or cut-section principle As shown, the sections extend from signal to signal exactly, and there are no distant signals These were not provided in the earliest installations

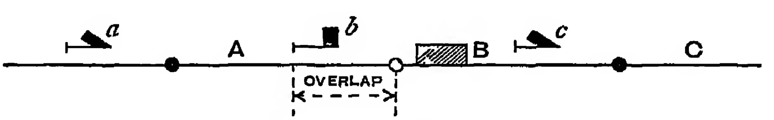


Fig 197 —Signals with Overlap

A train had to approach each signal prepared to stop at it if necessary, and if the preceding train were only just beyond the signal, a collision might occur if the driver of the second train overran the stop signal

Overlap —To guard against this the "overlap" was introduced This is shown in fig 197 The signals are placed at some distance in the rear of the dividing points, between sections, so that a train does not approach a stop signal unless the line is clear for a certain distance ahead of it This distance is the overlap, and it gives a certain amount of margin to pull up in if a stop signal is passed

Separate Section Overlap.—In fig 197 a train running in an overlap does not control the signal immediately in the rear of it, but is only protected by the second signal in the rear If it should be stopped in the

overlap from some cause, and a second train should pass the stop signal under caution, it may be misled by the clear signal, and, resuming speed, run into the disabled train To avoid any possibility of this it is better to make the overlap a separate track-circuit section controlling the two signals next in the rear of it, as shown in fig 198

Distant Signals —Automatic signals may be and to-day almost always are provided with distant signals, which may be on separate posts or combined with the rear stop signal when the sections are of a length to permit this, as shown in fig 199 Three-position signals [1] can be substituted for

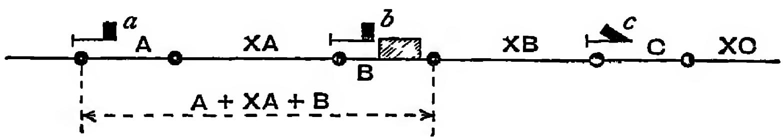


Fig 198 —Separate Section Overlap

the combined home and distant signals Overlaps may be provided with distant signals, but some installations do not have them, it being considered that the distant indication is sufficient warning to enable the stop signal to be observed Where automatic train stops are employed working with stop signals, as on many electric railways, an overlap must be provided in order to render the automatic stop useful under all circumstances, to work without overlaps it would be necessary to have some system of positive speed control which would bring a train to a stand at a stop signal independently of the driver, as some systems have been designed to do The overlap is not a fixed distance, as it is in manual block working, but varies

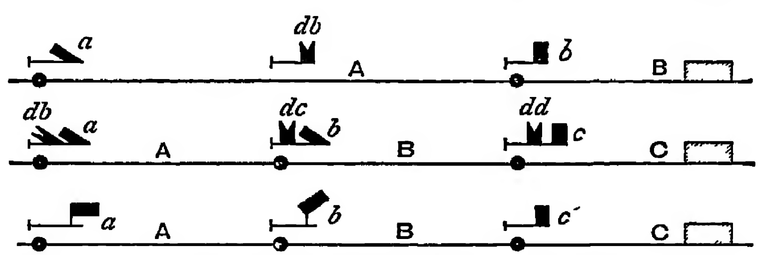


Fig 199 —Distant Signals and Three-position Signals

according to gradient and other circumstances, being calculated for each signal

Full Block Overlap —When the block sections are very short, the overlap itself becomes equal to a block section, as shown in fig 200, where the system in use on the New York Subway is given

Normal Position of Signals —In the earliest installations the signals always showed clear unless the line which they governed was occupied by a train, and they thus reflected exactly the state of the line As the first automatic signals were not very reliable, and sometimes remained at clear

[1] See Chapter V, p 50

when a train passed, it became the practice to require drivers to see the signals change from stop to clear as they approached them, in order to detect any such failure—the signals remaining at stop at all times unless a train was actually approaching This system was known as the " normal danger " system, to distinguish it from the other, called " normal clear " It was soon found quite impossible to require drivers to see each signal cleared, and the " normal danger " system was modified so as to allow the signals to assume the clear position in time enough to give a clear distant signal to the train where such signals were in use So arranged the " normal danger " system is employed to a certain extent in America and France, and in one British installation, but the great majority of installations are operated on the " normal clear " plan The advantages of the " normal danger " system are that energy is not wasted in holding the signals in the clear position for long periods, and that they are less likely to stick in the clear position through frost, snow, &c , as they are only at clear for a short time This latter argument has, however, no weight if the traffic is very

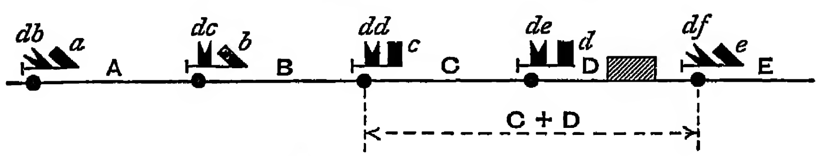


Fig 200 —Full Block Overlap

dense, as the signals have then no opportunity to remain at danger with the section unoccupied, there being always another train approaching The first argument has practically no force when light signals [1] are used, and as these are coming more and more into favour it is probable that the " normal danger " system will not be used much in future Methods of proving that signals assume the stop position behind each train are now in use which remove all danger due to failures in the clear position

Boston and Maine Signal Checking System.—On the Boston and Maine Railway, United States, the signals are normally at clear, but go to stop before the engine reaches them, the driver being required to see that this occurs If the signal does not change it must be regarded as a stop signal Trains finding a signal at stop must not proceed close up to it, but stop clear of a special post, called the block limit post, placed at the track-circuit dividing point This is an equivalent of the original " normal danger " idea, and was designed for the same purpose

Arrangement of Sections and Signals —There are several factors which in varying degree, according to the circumstances under which it has to work, have to be taken into account in laying down an installation of automatic signals The length of the sections has to be decided upon according to the nature and intensity of the traffic, so that the signals while protecting the trains expedite their movements as much as possible Where

[1] See Chapter XI

automatic signalling is used, as it frequently is in America, on lines of comparatively light traffic because no other form of signalling is workable, the question is not very difficult to deal with, but as soon as a suburban or metropolitan train service comes to be considered where trains follow one another at close intervals, the location of automatic signalling sections requires carrying out with great care

The conditions governing the length of a block section and therefore the number of trains which can be run are (*a*) the speed, (*b*) the maximum distance required to stop in, which depends upon brake power, (*c*) the gradient, (*d*) the time required for the signals to change,[1] (*e*) the length of the train, (*f*) local features such as stations, &c , which influence the placing of signals and the train movements

Generally speaking the number of trains that may be run depends upon the speed, and therefore to provide for a maximum service it must be possible to run at a high average speed, which in turn requires that the signals shall be so arranged and worked that this may be done with safety This means that a stop signal must always be preceded by a distant signal of some kind so that a train running at maximum speed can be pulled up in time Braking power thus becomes as important as the signals, and when trains of various speeds and braking power have to be run over the same track it gives rise to the problem of signalling for two braking distances or two classes of traffic Every change in speed materially affects the braking distance, as within certain limits the latter increases roughly as the square of the speed Short block sections can be provided, and high average speeds maintained if the signals give sufficient indication to the engineman to enable speed to be reduced in time, which, in other words, means providing more than one distant indication This is done in the three-block indication system of the Pennsylvania Railway, which has been adopted in Victoria and elsewhere, and in the Belgian State Railways Code; these are both described in Chapter V In both cases a certain minimum stopping distance is assumed for reduced speed running, for which the ordinary distant indication can be given at the correct point, but in order that trains running at a high speed shall be able to obey it, an additional indication calling for reduced speed is given beforehand at such distance away that the required speed reduction can be made before the ordinary distant indication is reached For maximum speed to be maintained it is evident that a train must be able to run with clear signals, and therefore the preceding train must be so far ahead that clear signals are exhibited in time to be seen properly It is thus necessary to allow a certain amount of time for the driver of a train to read and interpret the clear indication, which must be reckoned with in computing the interval at which trains can follow one another without check If automatic signalling were always confined to a perfectly regular succession of signals on a track having no sidings, stations, &c , along it, there would, at all events in theory, be no difficulty in deciding the best positions for the signals, but in practice it

[1] This is negligible with light signals

often becomes very difficult to meet the requirements which the presence of stations, junctions, &c , calls for, as signals cannot be placed anywhere but must stand in correct relation to these On suburban lines station stops exercise a very great influence on the spacing of trains, and special signalling arrangements, referred to later, are necessary to minimize the effects produced by such stops on the column of traffic that is following

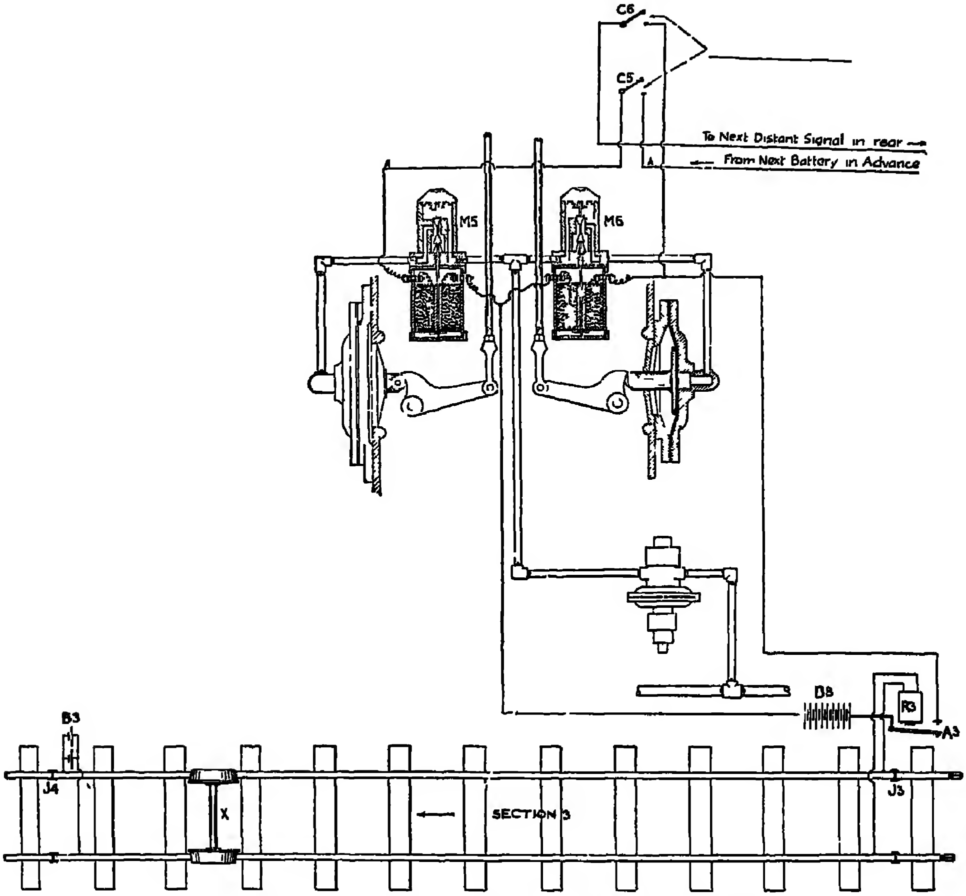


Fig 201 —Automatic Signal, Low-pressure Pneumatic System

The ability to deal rapidly with trains at stations, and above all at the terminal stations, is really the crucial factor in handling a dense traffic, and frequently imposes a minimum train interval much greater than would be attainable if this point had not to be considered When, however, a line is signalled for and worked up to an extremely close train interval, with the aid of well organized station working and other details, it has the disadvantage that there is practically no margin to recover in if the slightest thing goes wrong An unusual station delay, which is always liable to occur, reacts immediately on the whole service, and it may take several hours to get rid of a dislocation

in the schedule that is easily caused in a few minutes or even seconds [1]

Installations and Systems —There are so many installations in use now that only a few representative types can be dealt with here The same remark applies to the apparatus employed, which has undergone a remarkable development since automatic signals were first introduced One of the earliest signals ever used was Hall's disc signal, still in service in America and France It consists of a banner made of silk moved in front of an opening in a case by an electromagnetic movement, a coloured spectacle above moving in front of a lamp to give the night signals This signal is very reliable and simple, but has the disadvantage that snow can completely cover the case and obscure the indication Semaphore signals were introduced later, and now light signals have begun to supplant the semaphore Electricity is the most generally used motive power for automatic signals, but semaphores are sometimes operated by compressed air or compressed carbonic acid gas,[2] electrically controlled

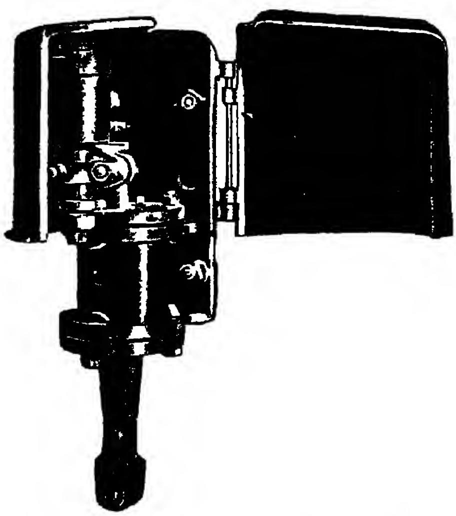


Fig 202 —Electro-pneumatic Motor for Signal

Low - pressure Pneumatic Signal —This has been installed extensively on the Southern Railway (South-Western) main line The post is tubular and the operating rods are inside, the operating mechanism being contained in the base of the post, which is a cast-iron case

Fig 201 is an illustration of the mechanism The main air pipe passes through a reducing valve which reduces the pressure to 10 lb per square inch, it then has to pass an electromagnetic valve which governs its admission to the diaphragm A plunger rests upon the face of the diaphragm and terminates in a roller which comes into contact with a crank in connection with the down rod of the signal

When the block section is unoccupied the electromagnetic valve is energized, thereby admitting air to the diaphragm and causing the plunger to be forced outward The roller then comes into contact with the crank, which has the effect of raising it and so causing the down rod to be lifted and the signal arm to be lowered

[1] For a full discussion of the question of locating automatic signals, see H G Brown, "The Signalling of a Rapid Transit Railway" (*Proc Inst Elec Engineers*, April, 1914), and R S Proud, " Location of Signals as an Aid to Traffic Working " (*Proc Inst Railway Signal Engineers*, Session 1922–3), as well as the works of Kemmann, Prache, and Delacourt, &c referred to in the bibliography

[2] Electro-gas signals have not been much installed in recent years, except in Germany as power distant signals

Any failure in the current or the air supply simply allows the arm to fly to danger by gravity

Electro-pneumatic Signal —Fig 202 shows the motor as fitted to

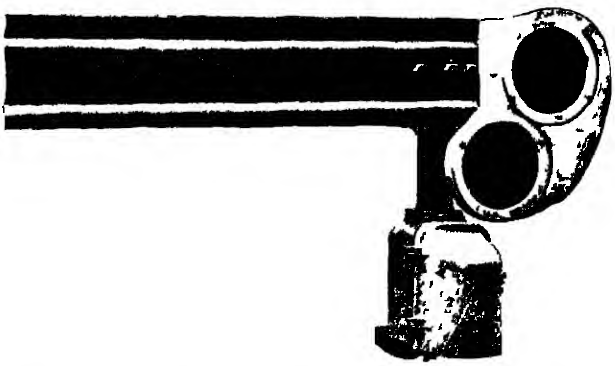


Fig 203 —Electro-pneumatic Self-contained Signal Arm and Motor

an existing signal post The air is admitted to the cylinder by means of an electromagnetic pin valve, causing the piston to be forced downwards and the signal to be lowered

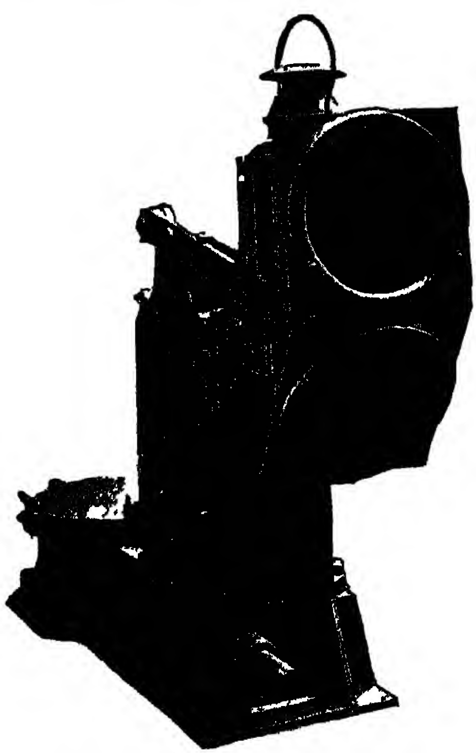


Fig 204 —Electro-pneumatic Tunnel Signal

Directly the current is cut off, the electromagnet becomes de-energized and cuts off the supply of air, at the same time opening the exhaust The arm now returns to danger by gravity, but, having to displace the air in the cylinder, the movement is not so sudden as with any other form of motor The pressure of air in the main varies from 65 to 70 lb per square inch

Some engineers prefer a self-contained motor signal in which the motor and semaphore arm are fixed on the one support Fig 203 illustrates a neat form of apparatus of this type The rod connection from the motor to the arm passes inside the tubular casting and is therefore well protected against frost and snow

Electro-pneumatic Tunnel and Tube Signals —In places where an arm is not visible, and only a light indication is necessary, the tunnel signal shown in fig 204 is used The upper glass of the spectacle is red and the lower one green It is raised by means of an air motor inside the

base casting A tube railway signal, similar in construction to the tunnel signal, but narrower and adapted for fixing on the sides of the tube instead of being placed in the six-foot way, is also used These signals are made by the Westinghouse Brake and Saxby Signal Company

Sykes' Signal Motor —Fig 205 illustrates the type which is constructed for use with primary batteries The casting A is directly connected to the crank on the outside of the case, from which the movement is transmitted to the signal arm through the usual balance lever Mounted behind the casting A is a worm wheel which carries two studs near to its rim, so that when the wheel is rotated by the action of the motor through the gear wheels and worm shaft, one of the studs comes into contact with a halved axle carrying the lever B, and the latter is attached by a link C to the armature D of the holding-off coil E A switch F and a dash pot complete the mechanism

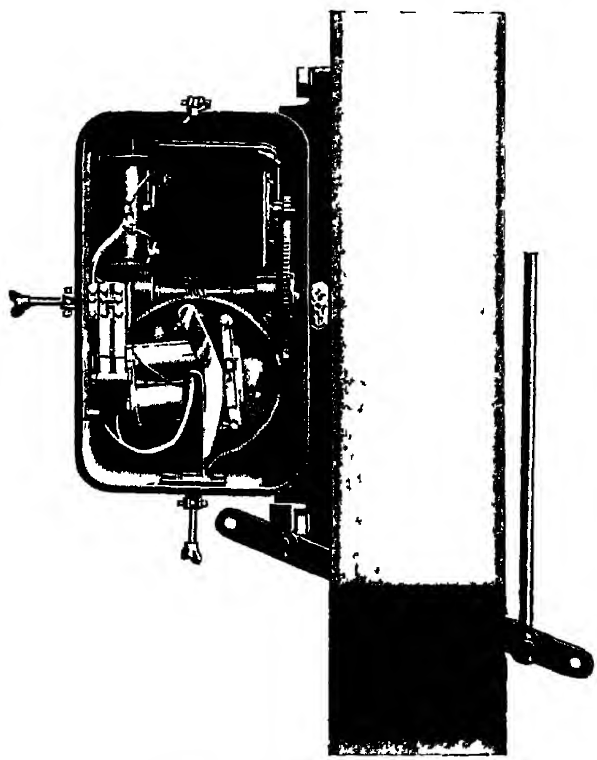


Fig 205 —Sykes' Signal Motor

The action is as follows Current passes through the holding-off coil and the motor in parallel The armature is held up to the magnet and, through the link, prevents the lever with its halved axle from moving, so that one of the studs on the worm wheel, coming into contact with the halved axle, rotates the casting A until the switch cuts off current from the motor, when the signal is fully lowered When current in the holding-off coil E is cut off, the armature can no longer hold up the lever B, and so the halved axle turns in its bearing sufficiently to allow it to clear the stud upon the worm wheel and the signal arm resumes the danger position by gravity, under control of the dashpot

Sykes' Tunnel Signal —Fig 206 illustrates this arrangement, which consists of a spectacle holding a red and a green glass, which is operated by means of a pair of coils in a similar way to the banner signal Owing to its narrow construction it can conveniently be used in tube railways, and other places where the clearance is very small.

Top-mast Signal.—Some electric signal mechanisms are arranged to fix directly on the spindle of the semaphore, and thus dispense with up and down rods and fittings This is a very neat arrangement, but has the disadvantage that the lineman has to ascend the post to examine the mechanism, which is not very convenient especially in bad weather There is a very great number of such mechanisms at the present time Fig 207 shows one operating a two-position upper quadrant signal on the Metropolitan Railway, made by the Westinghouse Brake and Saxby Signal

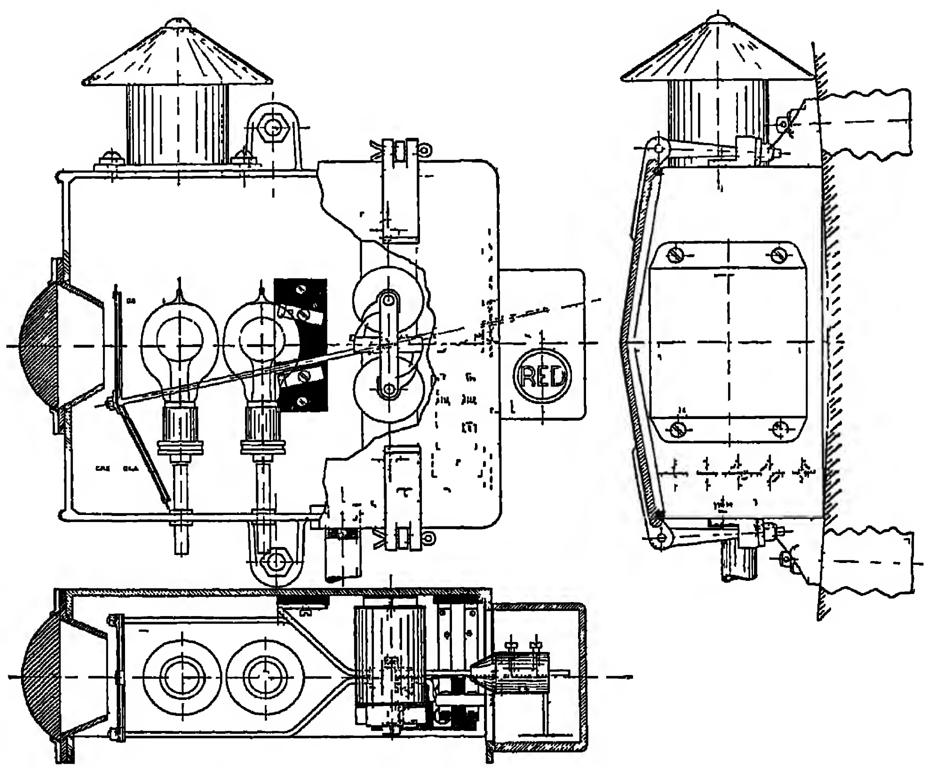


Fig 206 —Sykes' Tunnel Signal, Waterloo and City Railway

Company Fig 208 shows another mechanism, for a three-position signal, supplied by the British Power Railway Signal Company Signals equipped with the Federal Signal Company's mechanisms and fitted on an American railway are seen in fig 209 [1]

Light Signals —These are described in Chapter XI, and may be used in place of semaphores in automatic signalling Fig 210 shows a three-aspect light signal on an American electric railway

Automatic Signal Circuits.—The arrangement of these depends on several factors, and there are a great many schemes in use Besides the control circuits themselves there are also, in the case of electric systems,

[1] The illustration represents a double line, each line being signalled for traffic in both directions on the A P B system, described in Chapter VII, p 78

the main supply wires or cables to be considered For such installations alternating current is now regarded as the most up-to-date source of energy It lends itself readily to all purposes Transformers have no moving parts, so that current can be obtained economically at various voltages for different functions Where compressed air is used, supply mains must of course be provided throughout the work Gas signals require no mains,

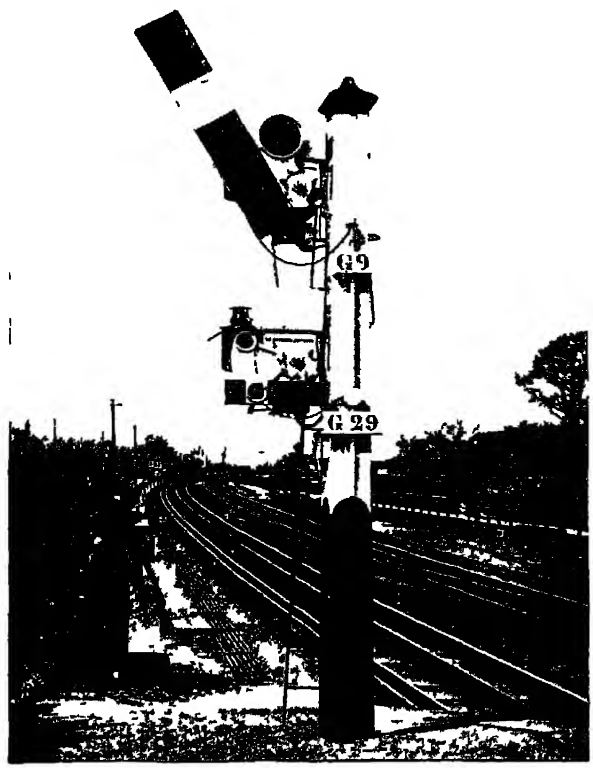


Fig 207—Two-position Top-mast Signal

the signals having reservoirs of gas, which are changed at intervals A few typical control systems are illustrated

Low-pressure Pneumatic System—The circuits are shown in fig 211, and are very simple They relate to the signal in fig 201 Each track circuit is fed by a battery of two (or more) cells in parallel, B^1, B^2, B^3, at the leaving end of each section

The relays are marked R^1, R^2, R^3, R^4 Each semaphore is provided with an electro-pneumatic valve and magnet M^1, M^2, M^3, M^4, M^5, M^6, M^7, M^8, the action of which is to admit air at a pressure of 10 lb per square inch to the signal diaphragm operating the piston, and thereby moving the signal (which is attached to the piston by means of a rod and crank) to the clear position

In order to prevent the possibility of (1) the distant signal being in the clear position when the home arm above it is at danger, (2) the distant in the next section behind being in a contrary position to the home signal under consideration, the circuit-breaker springs C^6 are inserted in the circuit A, A, which operates the distant signal, this circuit deriving its current from the operating battery of the next home signal ahead

C^5 are similar circuit-breaker springs inserted in the circuit operating the distant signal in the next section back, which indicates at the previous section the position of the home signal under consideration The above mentioned circuits are made or broken by a circuit-breaker working in direct connection with the home arm

In fig 211 a train is represented by a pair of wheels as having passed signal 3 and entered section 3, which extends from J^3 to J^4 The action has been to short-circuit battery B^2, de-energizing relay R^3, allowing its armature A^3 to fall away and break the circuit through M^6 and B^8, thereby de-energizing magnet M^6 and shutting off the air pressure to the diaphragm, thus causing the signal to fall to danger by gravity

It will be noticed that the train is always protected by a home and distant signal at danger, the latter being a whole section in the rear There are no overlap sections in this system

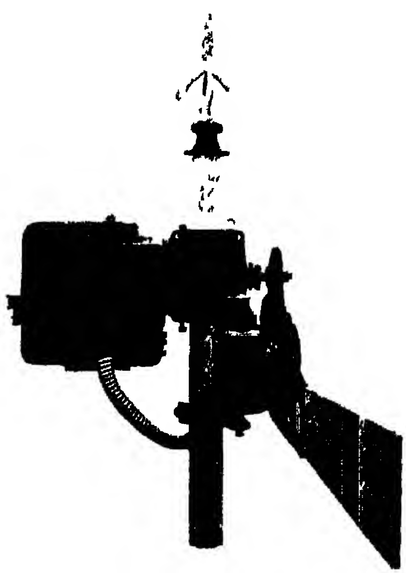


Fig 208 —Three-position Top-mast Signal

Hall System —The system used in this country is on the "normal danger" principle, with overlaps of 400 yd The signals are electro-gas signals Fig 212 is a diagram of the circuits The clearing relays A are normally de-energized owing to the batteries E being insufficient to lift the armatures in consequence of relays C being in series with them When a train enters the section, relay C in the rear is shunted, and, owing to the resistance in the circuit being reduced, relay A now picks up its armature, and so closes the contact to the electromagnetic valve controlling the admission of gas to the cylinder operating the signal

In the diagram a train is shown standing at No 2 home signal, whilst another is travelling between Nos 4 and 6 home signals The foremost train has just crossed the overlap joint and is half in the overlap and half in the main section, in consequence of which relay A^3 is energized thereby, closing the circuit through the electro-gas valve G^3 of the distant signal No 5, and relay C^2 de-energized, which cuts off the operating battery

F^2 of the home signal in the rear and closes the bottom contact in the circuit of electro-gas valve H^3 of home signal No 6

Directly the foremost train clears the overlap section, relay B^2 is energized, battery E^2 joined up, and relay C^1 energized, joining up battery F^1 through middle contact of relay B^1, electro-gas valve H^1 of home signal

Fig 209 —Signals with Top-mast Mechanisms on an American Railway (See footnote on p 152)

No 2, relay D^1 and bottom contact of relay C in the rear (not shown on diagram), which is de-energized owing to the train being in the section

It would appear from the foregoing that No 2 home signal would therefore be lowered, but this does not take place owing to a resistance and relay D^1 being in circuit There is, however, sufficient current flowing in the circuit to energize the relay D^2, which then reduces the resistance in the circuit by providing a shorter path for the current, and immediately this takes place sufficient current passes through the electro-gas valve to operate it and so lower the signal

The lowering of the arm closes the two pairs of contact springs No 2, one of which places a shunt across the relay D^1, causing it to drop again, and once more diverting the current through the contact springs of the home signal in the rear and clearing relay A to the electro-gas valve of the corresponding distant signal These circuits illustrate the system as at first installed on the London and North-Eastern Railway There are several other "normal danger" circuit arrangements

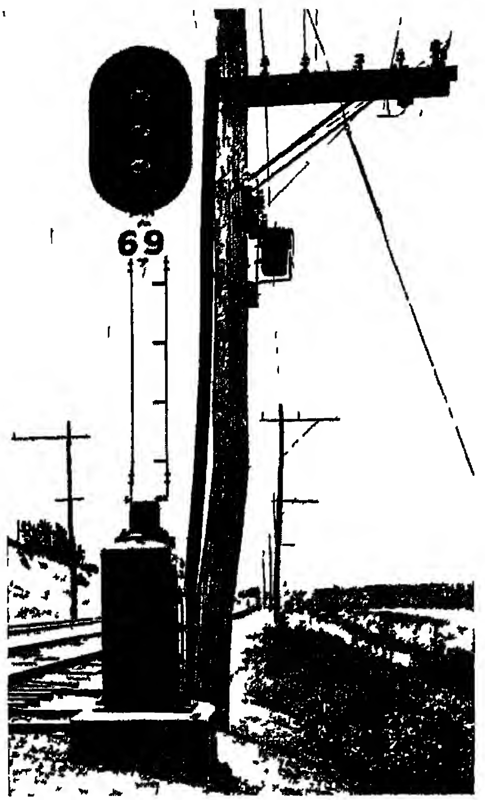


Fig 210 —Three-aspect Automatic Light Signal on American Railway

London Underground System — The original installations were laid down with Brown's circuits, illustrated in fig 191, but all recent extensions have been provided with alternating-current apparatus

Alternating - current Systems — Generally speaking the circuits do not vary very much in these systems from those used with any of the continuous-current systems, except for certain minor details due to the design of the relays, &c Alternating-current track circuits are dealt with in Chapter IX, and apparatus therein described is employed in combination to control the signals so that the same schemes can be realized as with battery-fed track circuits From the traffic working standpoint there is no difference, it is simply in technical details that this occurs

Control of Distant Signals.— Distant signals, or repeater signals as these are frequently termed on rapid transit lines since they do not exactly correspond to distant signals as understood in main-line working, are controlled by the position of a stop signal ahead, and in a few cases by more than one This control may be effected directly over a line wire, with or, less frequently, without a line relay, as in fig 213 Stop signal *a*, by means of switch S worked by the arm, energizes the motor M of the distant signal *da* from battery B over the line wire *l*, in the first example This is not a very good arrangement, as the voltage drop is likely to be large unless very heavy conductors are used For this reason it is usual to employ, as shown lower down on the sketch, a line relay R, of fairly high resistance, in the line circuit, the armature of which closes a local circuit

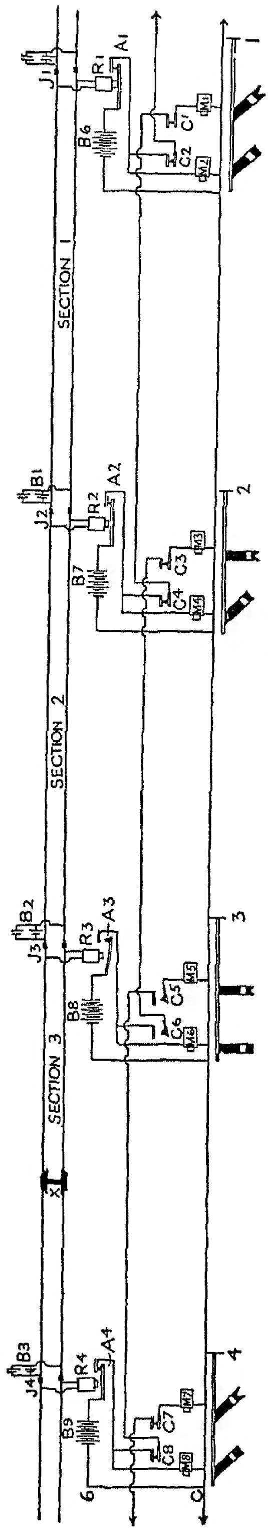


Fig 211 —Automatic Signalling Circuits Low-pressure Pneumatic System

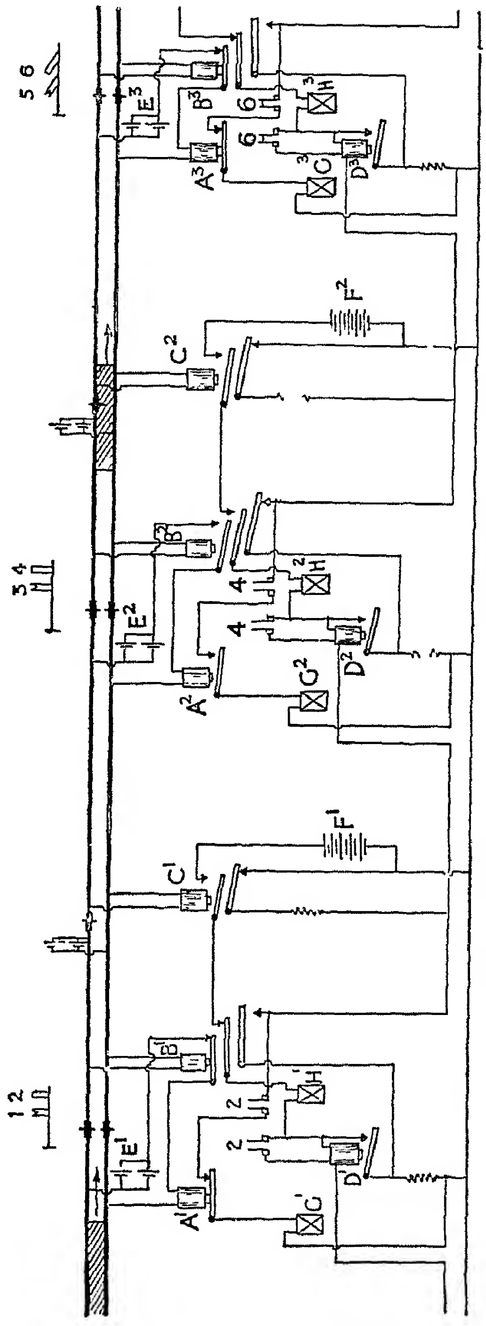


Fig 212 —Automatic Signalling Circuits Hall 'Normal Danger' System

from battery Y to motor M A line wire may be dispensed with altogether by employing a polarized track circuit, shown in fig 214 Signal *a* operates a commutator C which reverses the polarity of the track circuit between it and the distant signal The track relay T at the distant signal has, in addition to a neutral armature, a polarized armature which closes the

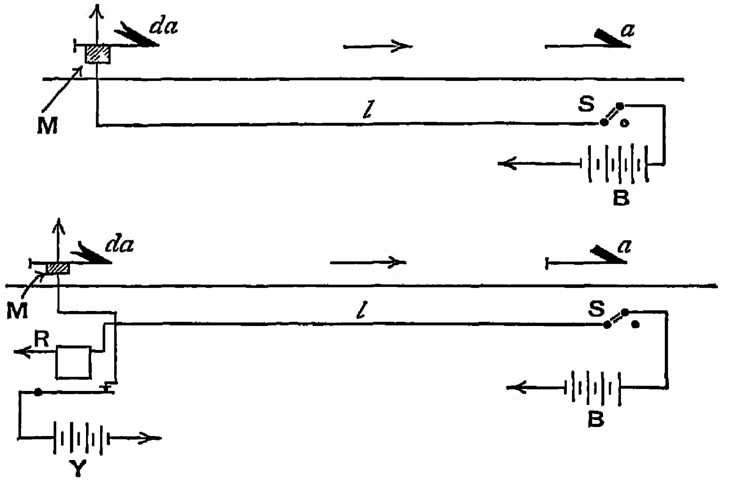


Fig 213 —Line Wire Control of Distant Signal

circuit to the distant signal motor M only when energized in the direction shown, that is when arm *a* is at clear If the distant arm is underneath a stop signal arm, the usual case where this system is in use, the neutral armature of the relay controls both arms, while the distant arm is, in addition, dependent on the position of the stop arm above and the polarized

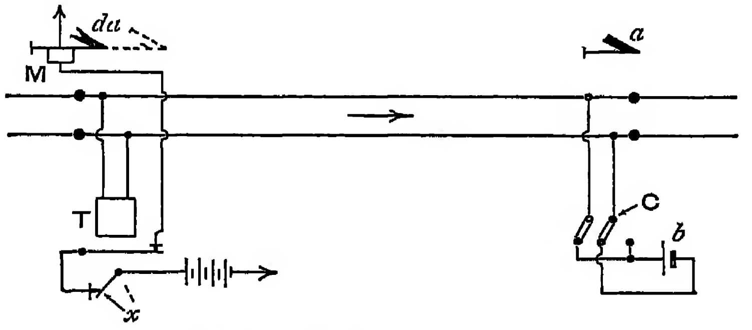


Fig 214 —Polarized Track-circuit Control

armature When the section is clear but signal *a* at stop, relay T is energized and allows the stop signal above the distant, where provided, to clear, but the polarized armature is held away from its contact, interrupting the circuit for the distant arm When signal *a* clears, the commutator C reverses the track feed connections, the armature *x* is reversed and closes the distant circuit If the stop signal above the distant is equipped with

a clutch-type signal motor it is made slow-releasing,[1] so that the arm does not fly back to stop during the reversal of the track current This polarized circuit is applicable to the control of three-position signals, from the 45° to the 90° position, and is employed in alternating- as well as continuous-current systems Many large installations of the circuit exist, especially in America, where the absence of line wires is found a great advantage in winter when sleet-storms sometimes entirely disorganize the wires over large areas

Proving Signals at Danger.—The security of any signal system, automatic or otherwise, depends on signals being returned to the stop position correctly, and not being left at clear when the line is occupied In many modern installations the circuit arrangements are such that each signal is detected as a train passes, and must be at stop to allow the one in the rear to clear again There are two ways of doing this One shown in

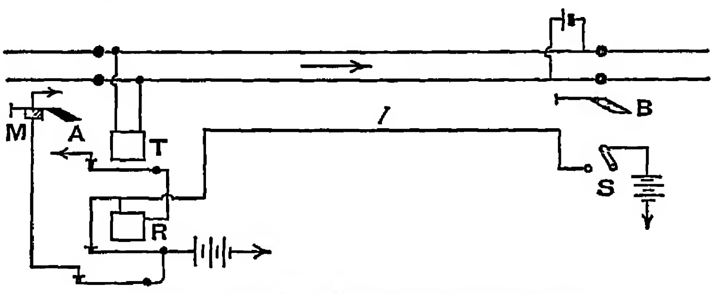


Fig 215 —Principle of Berlin Signal Detection Circuit

fig 215 is used on the Berlin Elevated Railway For simplicity battery circuits are shown, actually the system is an alternating-current one When a train passes signal A it de-energizes track relay T and thus also line relay R, which interrupts the circuit of A and places it at stop When the section is clear again line relay R cannot pick up unless signal B has returned to danger and switch S is closed This energizes R, which then remains energized although B afterwards clears, as it is a stick relay On the London Underground, Ceinture of Paris, &c , another method is used The track feed for a section is only complete when either the signal at its exit is at stop or the next section ahead is clear, and thus if a signal remains irregularly at clear behind a train the track section in the rear is not energized until the line is clear to the next signal working correctly This is a most valuable safety feature

Proving Automatic Train Stop.—When automatic train stops are in use, these are now usually detected in the same way to prove not only that they correctly operate after each train, but that they are intact and have not been damaged by passing equipment

Signals at Stations with Dense Traffic —The simplest automatic

[1] A slow-releasing relay or magnet has a copper tube over the core, the induced current in which prevents its sudden de-energization, and thus delays for an instant the release of the armature

signal arrangement at a station based on ordinary principles is shown in fig 216 A home signal *b* is provided which is controlled to a point beyond the starting signal *c* When a train is in the station a following train can reach signal *b*, but cannot start again until the first train has cleared its controlling point beyond the signal *c* The extent of the control on each

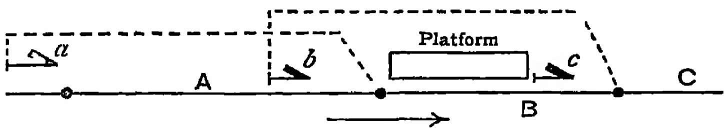


Fig 216 —Simple Automatic Signal Scheme at Stations

signal is shown in dotted lines In order to allow the second train to start earlier and thus follow the first one as it moves out of the station, a modified arrangement is now used at a great many places

Closing-up Signals —Fig 217 shows this arrangement The home signal *b1* is followed at short intervals by two others, *b2* and *b3*, controlled to the points shown, with the result that as a train passes out of the station

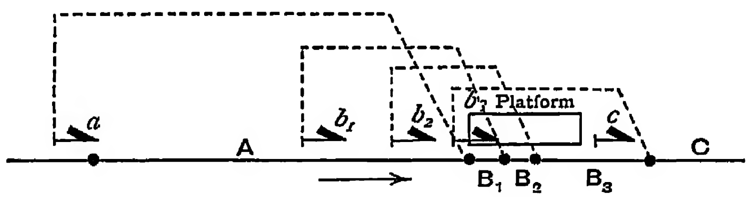


Fig 217 —Closing-up Home Signals

it causes these signals to clear in succession and permits the train behind to follow it at the earliest possible moment It is evident that this idea can be extended to a certain point, and four home signals are to be found at certain London Underground stations

Speed-control Signals.—Another method employed on the New York Subway is Waldron's speed control The fundamental idea of this, which is shown in fig 218, is to allow a train to come close up to a

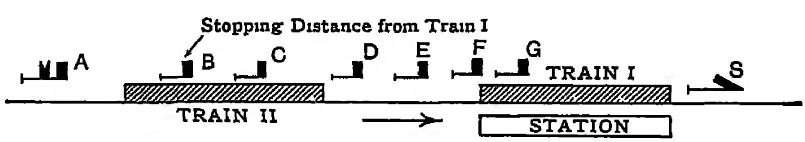


Fig 218 —Speed-control Signals

train in a station by compelling the driver to reduce speed to such an extent that the stopping distance is small, and there is still enough room to pull the train up in by means of the automatic stop, should the driver overrun the protecting signal

In fig 218, train I is in the station Signal B is held at stop and A at " prepare to stop ", that is top arm clear, bottom arm at caution B is full stopping distance from train I Train II on passing signal A sets a

timing mechanism in operation which clears B after a certain time interval has elapsed, which is fixed at such a figure that it compels the driver to reduce speed considerably before reaching B If he runs too quickly from A to B, B will not have cleared, and the automatic stop, fitted to all signals, will apply the brakes in the usual way Assuming, however, B clears in time, the same operation is repeated between B and C, but not between C and D This latter signal, and also E, F, and G, are controlled by train I leaving the station similarly to the closing-up signals already described This arrangement is very ingenious and appears to work well in practice It is open to the objection that a driver after passing C might at once accelerate, and overrun D at a higher speed than can safely be allowed for, but the possibility of this seems rather remote

Automatic Signalling and Interlockings —Where interlockings occur in automatic signalling areas the signals necessary for them must be worked in to form part of the automatic system with track-circuit control The signals should be semi-automatic with stick control, already described, but if the cabin can be closed at times, facilities should be given for rendering the main running signals entirely automatic, by pulling over a special lever, when the signalman goes off duty In order to get closing-up signals at interlockings, it may be necessary to fix automatic signals in between the interlocking signals, a method in use on the London Underground lines

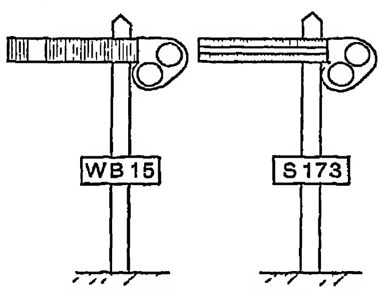


Fig 219 —Distinguishing Semi-automatic from Automatic Signals

Trains Stopped at Automatic Signals —Trains stopped at an automatic signal must be authorized to pass it, after a certain time interval if necessary, at slow speed, prepared to stop short of any obstruction, to prevent a defective signal from stopping the traffic entirely Interlocking signals ought not to be passed without written instructions from the signalman controlling them Some means of distinguishing the two types of signals must be adopted so that drivers can act accordingly Fig 219 shows the London Underground system The arms are painted differently, and each signal carries a number plate Interlocking signals have the code letters of the cabin concerned (WB, EN, EK, WO, &c), with the lever number, on their plates, while automatic signals have the letter S followed by a reference number Where a cabin is closed at times, and its signals work automatically, the special switching-out lever when pulled over illuminates a letter A on the signal, so that the driver knows that he may treat it as an automatic one Some railways do not paint the arms differently, but simply depend on the number plates for distinction In America a distinction is made on some lines by night and by day, there being two lamps on each signal, these being set in a vertical line on interlocking signals, but on opposite sides of the post on automatic signals As the driver does

not require to know what type of signal it is until he has stopped, a number plate distinction seems sufficient for practical purposes

Automatic Signals on Single Lines —Automatic signals are also used on single lines, but as they have to control opposing as well as following movements, the circuits are somewhat more complicated than those used for double-line working When first designed, the same general principles were followed as with double-line signals, the "line clear" indication being controlled by a certain length of track ahead of the signal, the extent of the control being such as to prevent opposing trains from colliding through passing clear signals simultaneously This is made clear in fig 220, where two opposing signals are shown, *a* and *b* With only one control section X there is nothing to prevent trains passing *a* and *b* at the same time, but by overlapping the control of *a* and *b* to additional sections Y and Z respectively, this can be avoided Such a simple arrangement is not satisfactory in practice, as it is necessary to have warning at the distant signals for *a* and *b* to avoid suddenly coming upon a danger signal, and the controls must therefore be overlapped much more than is shown in the figure What has to be accomplished is to ensure that, should two trains by mistake get between two crossing stations at the same time, they will each receive warning in

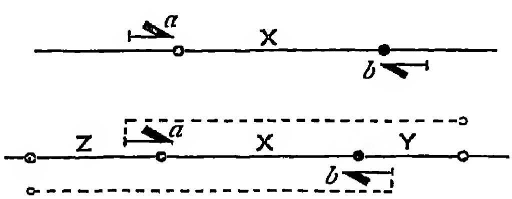
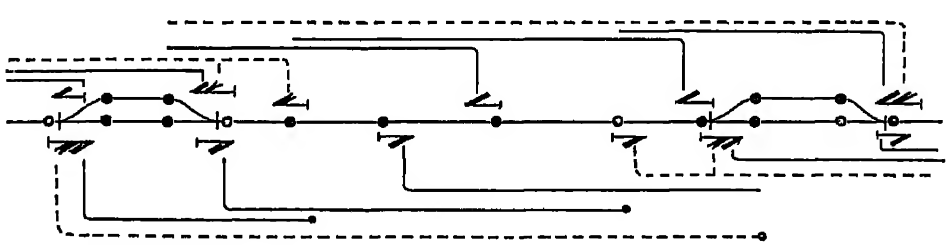


Fig 220



—— = *Home Signal control limits*
--- = *Distant Signal control limits*

Fig 221 —Straight Automatic Block System Ulster and Delaware Railway, U S A

time to pull up at stop signals situated at a minimum safe distance from one another This principle of control has been called "straight" automatic signalling to distinguish it from "selective" systems, which are described below Many installations are in service in the United States, and fig 221 is a diagram of one of them, showing the control limits for each signal If these are studied it will be seen that the conditions just laid down are fulfilled

The disadvantages of this system are (1) The signal indications do not remind a driver when he has forgotten that he has to wait for an opposing

train, nor can he, in any case, tell whether such train has or has not left the next crossing loop until it has approached near enough to control the starting signal (2) The controls have to be overlapped so far that they adversely affect following movements, the overlaps being much longer than is necessary for such movements, resulting in decreased track capacity To overcome these objections, "selective" systems were introduced in which the controls vary with the direction of traffic, and are not constant, as in the "straight" arrangement

A. P. B (Absolute-Permissive Block) System.—The principle

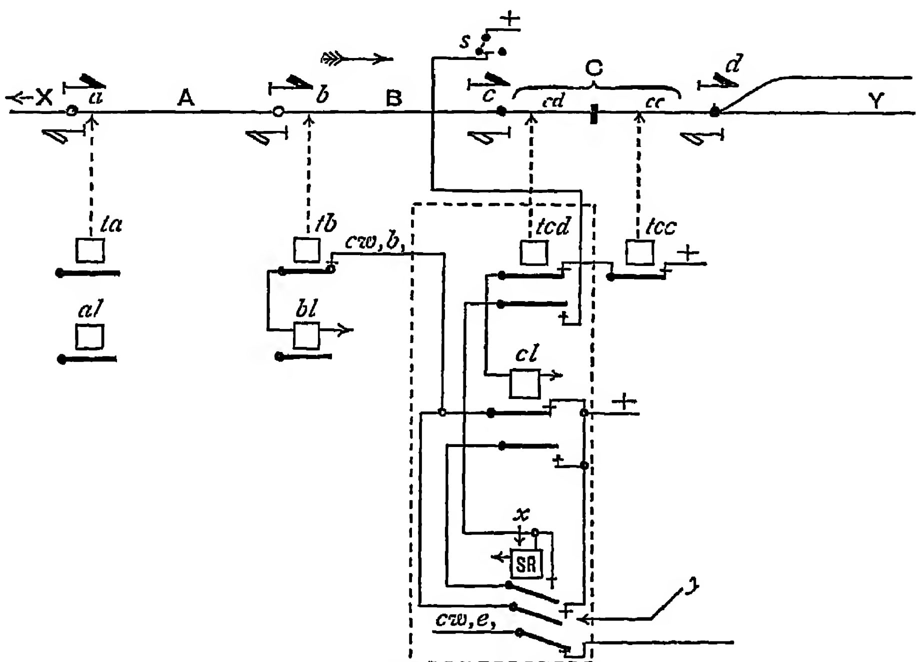


Fig 222 —Absolute-Permissive Block System Control Circuit

Note The purpose of the stick-relay x is to limit the control of signal *b* to the block-section B when a train passes signal *c*, *going in the direction of the arrow* Similar control is provided for the other signals

underlying this system is as follows The section between crossing loops acts as one for opposing movements, but may be subdivided into a number of sections for following movements with controls exactly as on double line There are different schemes in use, the first having been installed in 1911 by the late American Railway Signal Company Another system, which employed interlocking relays to do the selection, was for a time in use on the Burlington Railway, in the United States, but has now given place to the General Railway Signal Company's system, which has had a wide application in America and elsewhere The selection between up and down trains (as regards each signal) is made by means of a stick relay, and a simplified circuit diagram is shown in fig 222, where to avoid complication two-position signals are shown, without distant signals In order to under-

stand the system it is only necessary to consider the working of signals *b* and *c*, which control block-sections B and C respectively. Each signal is controlled by a line relay, *bl*, *cl*, &c., and in addition by a stick relay *x* (shown only for signal *c* in the figure) which operates in conjunction with a switch *s* attached to the signal arm of its own signal and the condition of the track section C immediately ahead. Each block section is subdivided into at least two track-circuit sections. In the figure only C is actually shown in this manner, in order to simplify the diagram. Should a train leave the crossing station Y, it de-energizes track relay *tcc* and thus also line relay *cl*, placing signal *c* to danger. The de-energization of *cl*, however, releases *bl* and places signal *b* to danger, and this similarly places signal *a* to danger and so on as far as the next crossing loop X, however many signals there may be. Thus a train leaving Y places all opposing signals to danger as far as X, and the control of signals *a*, *b*, and *c* extends to the far end of block section C. This is, of course, satisfactory for a train travelling from Y to X, but with a train going in the opposite direction, signal *a* must only be governed by block section A, signal *b* by block section B, and so on, to enable a second train to follow the first, just as if the line were double, at an interval of one block section. The stick relay is used to shorten the control of the signals in the following manner. Imagine a train passing signal *c* in the direction X to Y. It first de-energizes track relay *tcd* and thus also line relay *cl*, placing signal *c* to danger, but before the signal arm has time to open the switch *s* (which is closed except when the arm is at danger) the stick relay *x* is picked up over the back contact of relay *tcd*, and maintains itself over the back contact of relay *cl*. This establishes a battery feed via contact *y* to control wire *cw*, *b*, and thus energizes line relay *bl* directly block section B is clear. Signal *b* can then come to the clear position, although the train is running in block section C. When C is clear and *cl* relay once more energized, the stick relay is released. The reason for subdividing block section C will now be evident. When a train leaves Y and short-circuits track circuit *cc*, it places signal *c* to danger and thus opens the switch *s*, with the result that when *cd* is occupied later the stick relay is not energized as the switch interrupts its pick-up circuit. To avoid dangers arising from the stick relay remaining up or being picked up at the wrong time, the control of the opposing signal *e* is taken over a back contact on it, as seen by the wire *cw*, *e*. Each signal, for either direction, between X and Y is controlled in the manner indicated. When distant signals or three-position signals are used, the control for these may be carried out by any of the known methods, and does not affect the principles just discussed. As shown the signals all stand normally at clear, but in some installations of the A.P.B. system, the signals for leaving passing sidings stand normally at danger, and a push-button must be depressed to clear them, an electrical interlock circuit being arranged between the two signals. This method has some advantages, but is unsatisfactory where fast through trains have to be run. The principal advantages of the A.P.B. system are: (1) It indicates to the driver of a

train due to meet another train at a given siding, by the danger position of the starting signal, when the opposing train has left the next crossing loop, and thus prevents orders being overlooked or rules forgotten (2) It eliminates the long overlaps, which restrict following movements unnecessarily, that have to be used in the "straight" single-line signalling

Traffic-direction (T D. B) System —This is similar in principle, but the circuits are arranged differently It is used on inter-urban electric railways in America, where the signalling is comparatively simple, and only one set of intermediate signals is required between passing sidings. It has been developed by the Union Switch and Signal Company

Future of Automatic Signalling —The economic changes of recent years have given an added impetus to the adoption of automatic in place of manual signalling on main lines, while the increasing intensity of traffic on suburban lines renders its employment for metropolitan services indispensable The advent of the light signal and other simplifications has also made the path easier, so that it may confidently be predicted that the near future will see considerable extensions of automatic signalling in Great Britain and elsewhere

---

CHAPTER XI

Power Working of Points and Signals

Of late years junctions and yards have been enlarged to such an extent, in order to cope with the increase in traffic, that a manual signalling installation becomes too cumbersome by virtue of its magnitude For instance, the lead-out from the cabin forms a perfect network of rods and wires, and it is no easy matter to find the space to arrange the cranks and wheels to the best advantage Then, again, they form dangerous obstructions to railway servants unless they are properly covered in and this means, in a large yard, practically covering the whole of the ground, at very considerable expense

Points and signals are now located at greater distances from the cabin, locking bars are longer and heavier, several facing-point locks are required to be worked by the same lever, and in many other ways the work demanded of a mechanical installation becomes excessive

On the other hand, electric, pneumatic, or hydraulic power has much to recommend it Distance makes but very little difference to the working, any number of points or signals may be operated by the same lever, it is unaffected by variations of temperature, and it is quick and certain in its action

There is also a saving from a financial point of view, as, on account of the concentration in one cabin of an amount of work which was previously divided between a number of smaller cabins, there is a saving in labour,

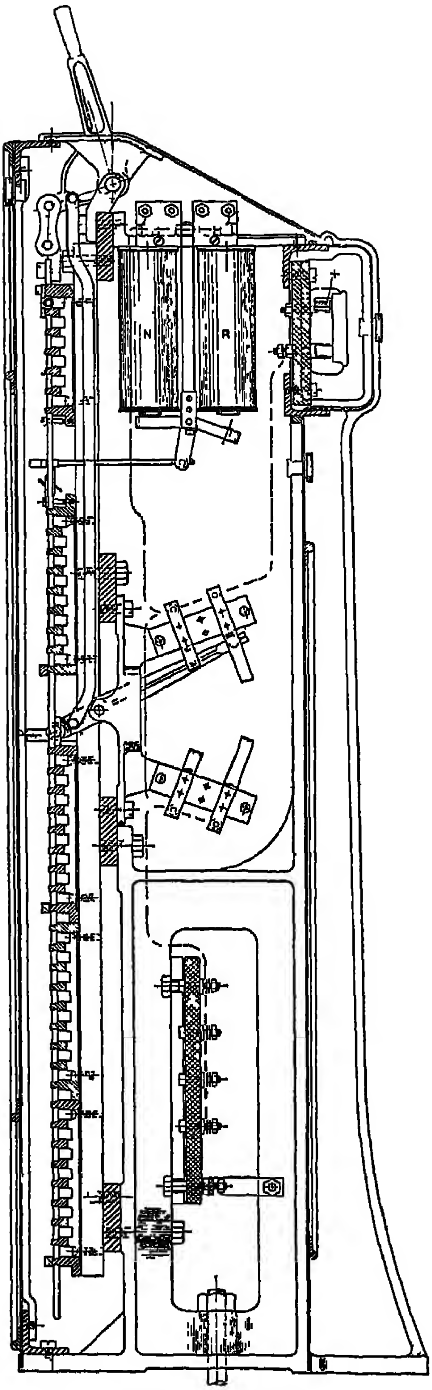


Fig 223 —Siemens Locking Frame

uniforms, lighting and heating This may seem of small account, but when it is possible to close several cabins the saving is represented by a considerable amount

Yet another advantage is that it needs only about half the staff to work a power box as compared with those required to work a mechanical box with the same number of levers This may save more than £500 per annum, which capitalized makes the greater first cost of power signalling justifiable It should be borne in mind, however, that owing to the intricate nature of the circuits generally a more highly trained maintenance staff is required

Each system, viz mechanical or power, has its advantages, and it is for the railway officer to decide which is best suited to the circumstances

In the descriptions which follow, it is proposed to take first the electrical systems in detail and afterwards the electro-pneumatic and electro-mechanical systems

Siemens All-electric System — In the Siemens system the current is derived from a battery of sixty-five accumulators, giving 140 volts, of a suitable capacity according to the number of motors to be worked Fig 223 is a cross-section of the locking frame The levers are spaced at 2-in centres, with the top of the handle 4 ft from floor level The frame is very narrow, being only 12½ in in width, and therefore does not obstruct the view of the signalman in places where the cabin is near the line

The frames are constructed in sections of sixteen levers, each lever having an engraved brass plate fixed in front of it, giving its number and the naming and releasing numbers Catch handles are dispensed with altogether, the lever being secured in its various positions by means of a spring bolt

Ordinary tappet locking is used, the tappet, which works vertically, being coupled to the lever through the medium of a link

The connecting rod between the lever and the switch is simply an additional connection, so that the tappet may be removed for alterations to the locking without rendering the lever unfit for use Check locking is provided to ensure that the signal or point motors have responded to the lever This is accomplished by means of two electromagnets which

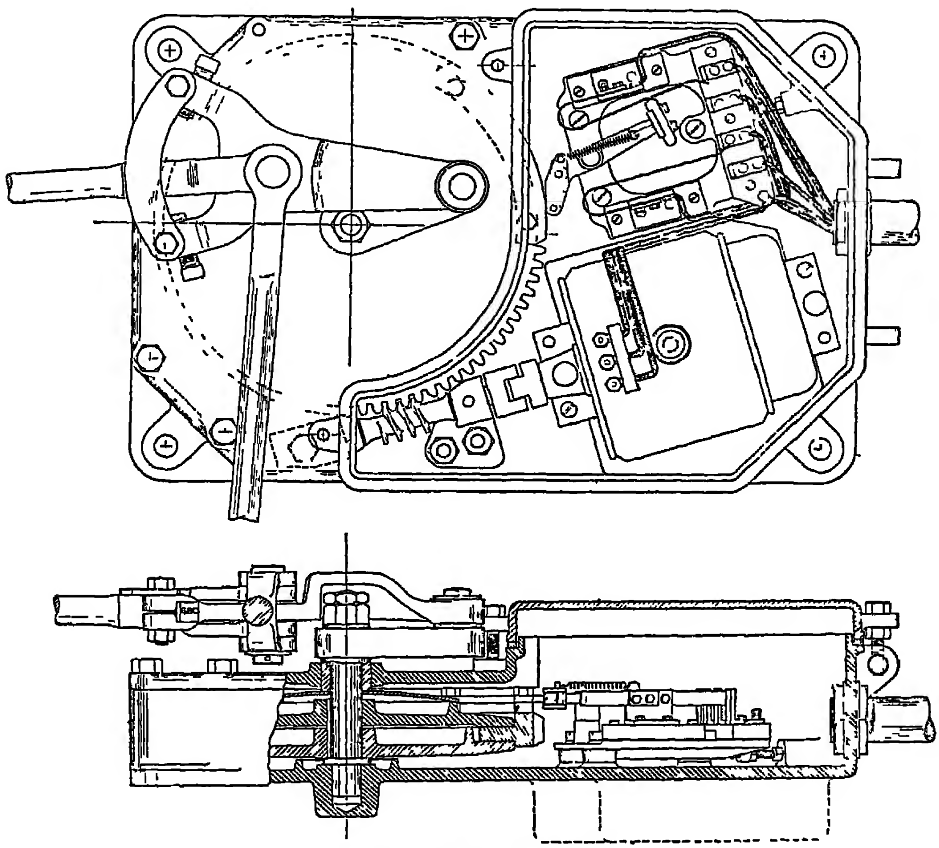


Fig 224—Special Toggle Gear

control a double armature, the latter being connected to a rod which engages with suitable slots in the tappet

The illustration shows a point lever which has two magnets, one being energized when the points are in their normal position and the other when in the reversed position A signal lever has but one magnet, as it is only necessary to check the lever if the signal has failed to go to danger Quick-break switches, having a long movement, are fitted, thus counteracting any tendency to arcing The front cover is removable, so that the fuses may be easily and quickly replaced by the signalman if necessary

The local wiring in the frame is coupled to a terminal board at the foot of the frame, so that it only remains to join up the line wires to the marked terminals in order to bring the frame into use This is also a great advantage for testing purposes

The point motor consists of a cast-iron box containing a reversible motor which operates a crank through a worm gear and friction clutch The latter is adjusted to slip in the event of an obstruction preventing the points from being moved, but in these circumstances the indication current to withdraw the check lock is not transmitted to the cabin The clutch has another function, viz to absorb the overrun of the motor after the points have closed For facing points having the usual lock bar and

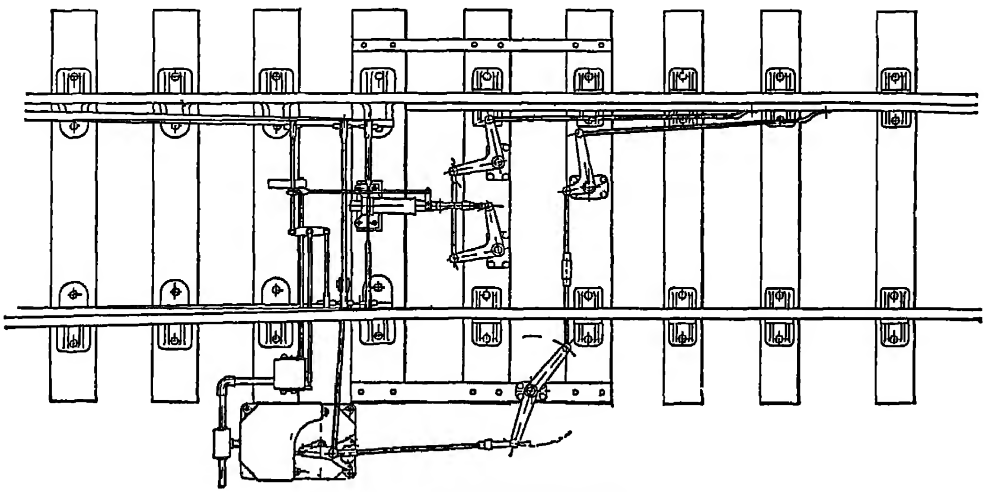


Fig 225 —Facing-point Lay-out

plunger bolt the crank has a movement of 320°, and is coupled to both the bar and the points by means of a special toggle gear, one type of which is shown in fig 224

A facing-point lay-out is shown in fig 225 In this arrangement the movement of the bolt is communicated through the lock bar, thus ensuring that the points will not be unbolted in the event of the bar breaking It will also be noticed that the detector rod is attached to the plunger bolt, so that the detection and check-lock circuits are only completed when the bolt is properly home

To operate a pair of trailing points the crank arm is coupled with the tongues direct and the toggle gear dispensed with

Fig 226 illustrates one type of detector This type detects by means of two cams, which are keyed to a shaft working from the plunger bolt When the rod attached to the points is moved, the tail end of the lever operating the crank arm comes into contact with the cam, and a movement is given to the crank which closes the contact springs If the bolt was not fully home the cam would not be raised, consequently the tail of the lever would simply swing over the cam and not move the crank The mechanism

for operating a semaphore signal is shown in fig 227 It consists of a light cast-iron case with movable ends, containing an electric motor and worm gearing, which rotates a shaft This shaft passes through the case

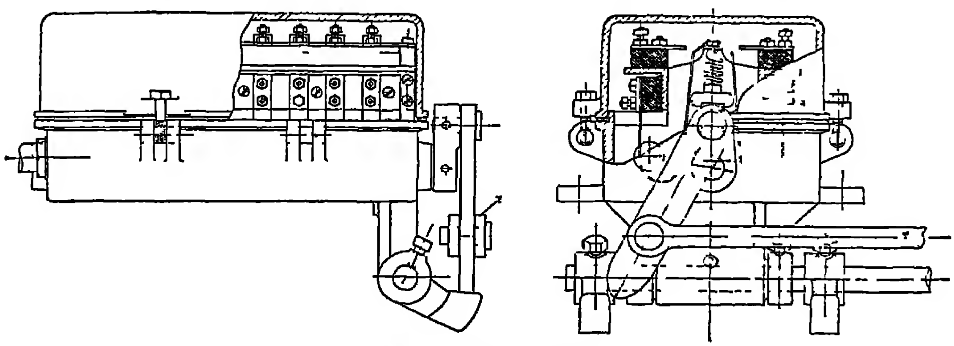


Fig 226—A Point Detector

and carries a pinion wheel, which is geared into a vertical rack, one end of which is attached to the lever plate at the foot of the signal post

A magnetic clutch, when energized, couples the motor, through the

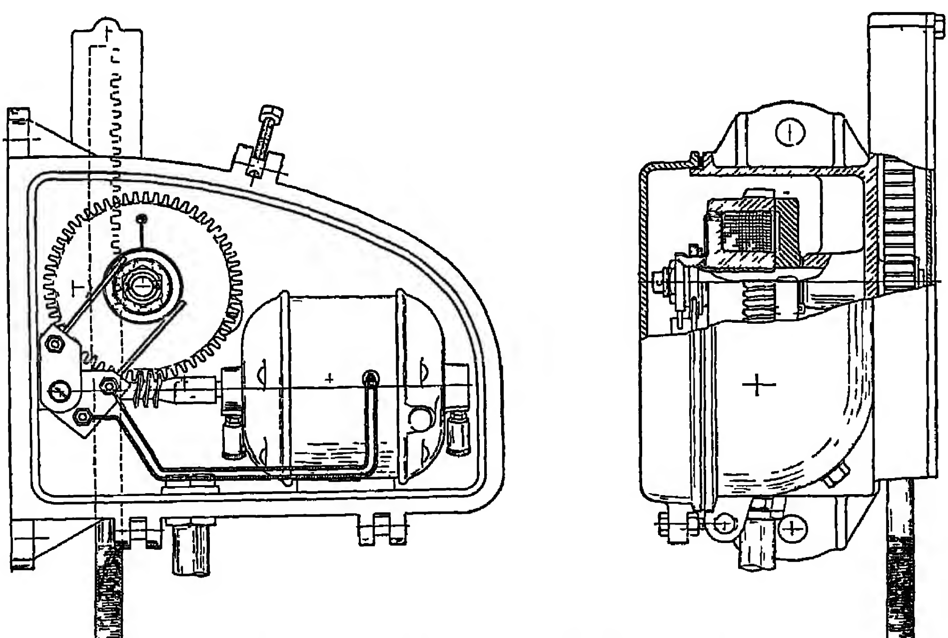


Fig 227—Mechanism for operating a Semaphore Signal

worm gearing and pinion, to the signal arm When the arm is fully lowered the motor circuit is automatically broken, but the clutch remains energized until the lever in the signal cabin is put back, when this is done the pinion wheel and shaft rotate without moving the worm wheel, and

so return the signal to danger A pawl locks the signal in its danger position to prevent it from being lowered wilfully

To electrically slot another signal, or for giving the return indication current, an electric switch is fitted to the signal post and actuated by a light rod direct from the signal arm

In the ground signal used in this system a white light is normally exhibited, which is obscured by a green glass fixed at the end of the small arm The mechanism is similar in construction to the signal gear, coupling magnets being used so that a two- or three-way signal only requires one motor Some of the details of this system, such as the point motor, point detector, &c , have lately been slightly altered and improved

The contacts in the locking frame and detector contacts at the points when not actually carrying current are earthed at one point, so that any stray current would pass to earth without affecting the apparatus

Installations of this system are to be found on the Great Western Railway at Didcot North Box, at Birmingham Snow Hill Station in the North and South Boxes, and at Hockley North Box

The Birmingham North Box is one of the largest power frames in England, having 224 levers Direct current at 140 volts is used to operate the motors This system was first installed in England in 1905

Ferriera-Insell One-lever Route-signalling System —An English system aiming at a reduction in the number of lever operations, and consequently less physical work for the signalman, besides a smaller frame, has been invented by Mr L M G Ferriera, of Messrs Siemens Bros & Co , and Mr R J Insell, signal engineer of the Great Western Railway It is an all-electric power system, the points and signals being operated by 120-volt direct-current reversible motors

The lay-out of a station yard is carefully divided up into routes, viz paths which vehicles or trains might be required to take In its passage a train could pass over more than one route under some conditions such as shunting These routes are controlled by one lever, which causes the points to move over into the right position and the appropriate signals to come " off "

Track-circuiting is employed to detect the presence of vehicles already on part of a route or fouling it, besides holding signals locked in the rear, or conflicting signals They also take the place of facing-point lock bars The position of points and signals is indicated by coloured lamps in the front of the locking frame

A " king " lever is provided which enables the points to be moved for repairs or emergency purposes, by releasing the interlocking, but while this release has been afforded the signals are locked in the danger position Slides in the front of the frame connected to electrical contacts switch on the power to the point motors, after the king lever has been pulled A vertical row of four coloured lights is provided behind each lever as an indicator

Normally the sequence of operations when setting a route is as follows:

1st position lever normal, red light (top) showing

2nd position lever pulled to 2nd position A search current energizes the track circuits, and if clear a white light, fourth in row, appears Also contactors close, and the motor for the points for the required route operate, should any of the points require moving Upon the check-lock release being obtained through the point detectors, the orange or third lamp lights

Should the track or route be fouled or occupied, the point motors cannot be moved nor a check-lock release obtained The retention of the red light, position 1, informs the signalman of the state of affairs

4th position upon receiving the check-lock release and seeing the orange light, the lever can be pulled to the 4th position, passing through the 3rd position in doing so This pulls off the signals, and the green light (second in row) appears when the arms are in the correct position

When the lever is restored, the first stage is to move it to the 3rd position referred to above, where it is held until the signals have returned to danger, and the green light is extinguished and the red reappears If vehicles are still on the route controlled by the lever, the check-lock release is not received and the white or fourth light is not shown

If the route is clear, the check-lock release is obtained and a white light appears, and the lever can then be moved to the full normal or 1st position

The points, however, do not move, but remain as they were, with the exception of " trap " points, which move to normal

As previously mentioned there are slides for each point-motor mechanism, which slides stand in a midway position in the ordinary way, and are locked in that position

There is also a king lever which is locked by all the other levers when any one of them is moved, and also locks them in the normal position when it is moved The king lever normally stands in the route or 2nd position and holds the point slides locked

Should it be required to move a pair of points separately, the king lever must be pulled, and this can only be done when all levers are normal The slides are then released and all signals are locked at danger A green light for normal and orange light for reverse is provided over each point slide

There being no point levers in the frame, the interlocking has to be done through the signals This adds to the complication, and involves more than the usual number of locks

The first installation of this system was put in at Winchester Great Western Railway and Southern Railway joint station in 1923 The new Great Western Railway station at Newport (Mon) is also to be signalled by this system

Crewe All-electric System.—It is a purely electric system used considerably on the North-Western section of the London Midland and Scottish Railway, and was first introduced more than twenty years ago It was manufactured by the Railway Signal Company Direct current

at 100 volts or 220 volts can be used The locking frame consists of the usual miniature levers in two tiers, the upper tier for the point levers and the lower one for the signals By this means it is possible to space them at $1\frac{3}{4}$-in centres Only the levers and the supporting frames are in the upper portion of the signal cabin, the switches, check locks, and mechanical locking being below the floor and operated by means of light rods attached to the lever tails

The mechanical locking is of the usual tappet type Immediately

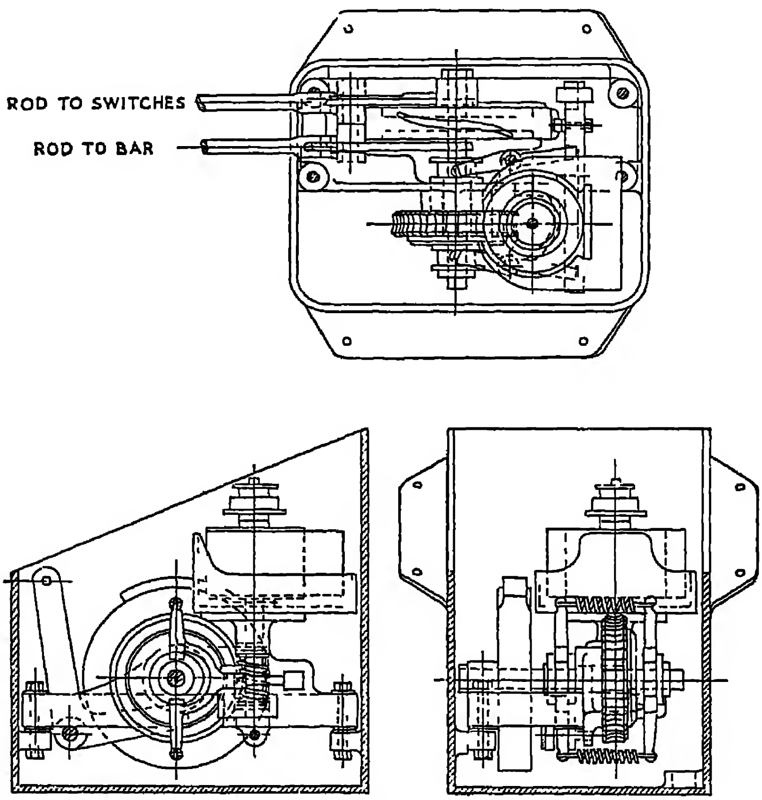


Fig 228 —Crewe Point Motor

below the locking are the switches, whereby the current is transmitted to the signals and points, and below the switches are the check locks These are only provided on the point levers, and prevent the full movement of the lever until the indication current has been received from the points in the usual way

The switch contacts are of carbon and are duplicated to ensure a good contact, and are carried on plungers which are held up by a spring

The check lock consists of two electromagnets having a pair of pawl armatures, which engage with suitable notches in a rod sliding vertically One coil is energized when the points are normal and the other when they are reversed

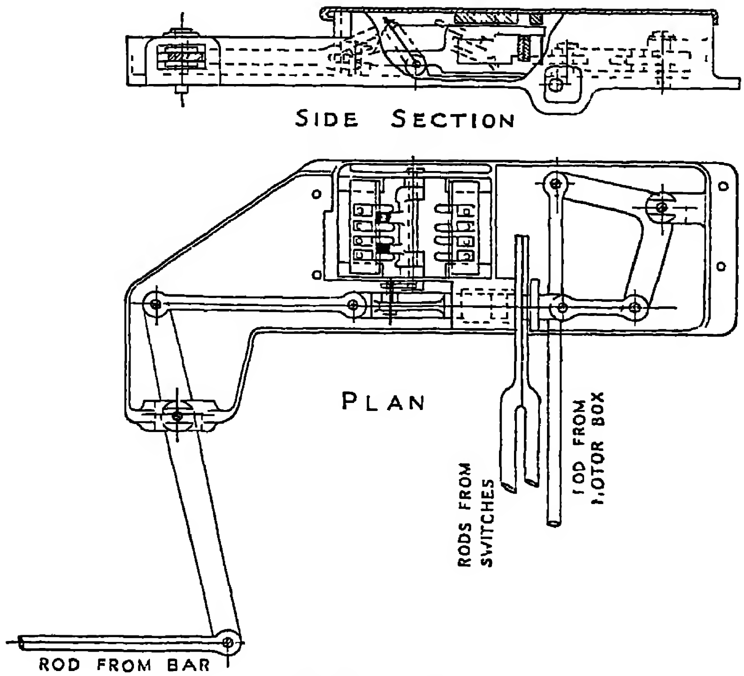


Fig 229 —Plunger Bolt and Electric Detector

One feature of this type of lever frame is that the check locks, switches, locking, &c , are all separate units, each being connected by a light rod, so that it becomes an easy matter to take out a defective part and replace it by a new one without throwing the lever out of use

Fig 228 shows the point motor It consists of an electric motor having an armature which fits over the shaft in such a way that it can be removed and a new one substituted in a few moments The shaft is fitted in ball bearings and gears with a worm and wheel The worm wheel is free to rotate upon a horizontal shaft unless connected to it by one of two clutches, which are fixed one on either side of it One clutch comes into action when the worm wheel is rotated in one direction, and the other when rotated in the opposite direction A cam wheel is rigidly connected to the same shaft, having an irregular-shaped channel formed on either side, into which works a roller attached to a crank One crank is for actuating the points and the other for the

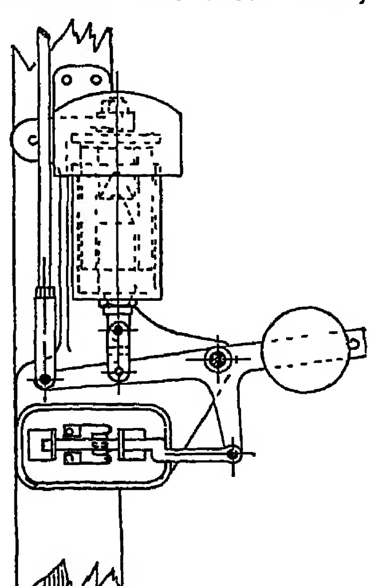


Fig 230 —Signal Magnet and Contact Box

plunger bolt and locking bar A striking gear for disconnecting the clutches comes into operation when the points have been moved and bolted, thus allowing the motor to have a slight overrun The whole of the mechanism is enclosed in a cast-iron box, which is fixed level with the top of the sleepers, and is afterwards half filled with a thick mineral oil

The motor takes about 20 amp at 100 volts and runs at 800 revolutions, thereby moving the points and bolting them in about three seconds

The plunger bolt and electric detector (fig 229) is contained in another cast-iron box, which is fixed by the side of the track on the opposite side to the motor box The detector contacts are for the signal detection and the check locking

Fig 230 illustrates a signal magnet and contact box This consists of an electromagnet combined with a solenoid, a carbon contact switch, and a small resistance A current of 15 amp at 100 volts is required to lower the arm When this has been done the switch cuts in the resistance, which reduces the holding-off current to 2 amp The arm, of course, flies to danger directly the current is cut off by means of replacing the lever in the signal box

A similar but slightly smaller arrangement is used in the ground disc signals

The Westinghouse Brake and Saxby Signal Company's All-electric Systems

Locking Frame—The miniature levers in the locking frame are spaced at 2½-in centres The frame is self-contained, and up to approximately eighty levers is entirely above the cabin floor level When the frame comprises a larger number of levers, the mechanical locking is sometimes extended below floor level The locking, which is of the bevel type, is fixed vertically in front of the frame, and is actuated by means of a connecting link, coupling the lever tail to a crank fixed on the upper end of a vertical shaft, thus imparting a rotary motion On this shaft is fixed a quadrant which engages with a horizontal locking bar on the rack-and-pinion principle

The levers, on being moved, also impart a rotary motion to horizontal shafts which run to the back of the frame On these shafts contacts of the air-break type are mounted by means of insulating bushes These shafts also carry locking quadrants which are controlled by the operation of electric magnets of either alternating or direct-current type, according to the supply used

A feature of this type of frame is that indications can be provided in the form of electric lamps mounted immediately behind the lever, and showing through apertures in the lever name plates For signal levers the indication consists of one light with a red lens, for indicating that the signal is correctly displaying the "danger" aspect For point levers two lights can be provided for indicating that the points have responded

correctly to the movement of the lever Other forms of indication can be provided if necessary

Where indication locks are required, the point levers are each provided with two electric locks which check the stroke of the lever in the indication positions, and release immediately the points are lying correctly and locked, thus ensuring that the road is properly set before the signalman can complete the stroke of the lever and set free his mechanical locking on other levers concerned Signal levers are provided with lock quadrants and electric locks for either back or approach locking, or for other purposes which conditions may require Each lock circuit is taken over a contact on its shaft, so that current is only applied to the lock coils when the lever is being moved Any failure of the indication circuit therefore results in the

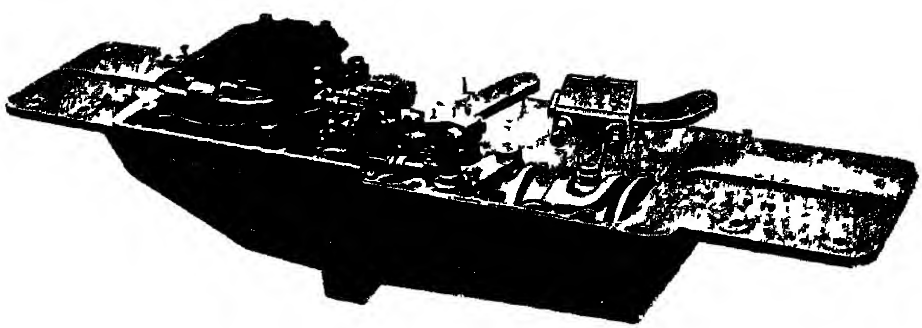


Fig 231 —Westinghouse Point Machine

indication lamps being unilluminated and the lever, in addition, being checked in its indication position until the fault is located and rectified

Point Machines.—The point machines are of two main types The type illustrated in fig 231 operates the points by means of a direct-current motor, through suitable gearing and a cam, so that the points are unlocked, thrown, and then relocked in the reverse position with one continuous movement of the cam The motor therefore rotates in the same direction during the whole of each point movement This machine is used for both high- and low-voltage work, the only difference being in the motor and gearing, and the source of supply may be either direct from power main, by hand generator, or from primary batteries, the two last-named adapting it for the operation of outlying points, in localities where ordinary power supply is not available, irrespective of their distance from the controlling cabin

Where the machine illustrated in fig 231 operates facing points a combined lock and detector is used, which is so designed that, in addition to locking the points in position, both point tongues and the lock must be in their correct respective positions before the indication or detection circuit is completed For trailing points a simpler detector is employed

Another style of machine, similar in design to that illustrated in fig 231,

is supplied where it is not necessary to operate a facing-point bolt

Another type of machine includes in its mechanism, in addition to that for moving the points, a point lock and detector A separate point lock and detector is therefore necessary This machine is operated by either alternating or high- or low-voltage direct current

Signal Machines —The electric signal machines are of the two- and three-position types, upper or lower quadrant, and are constructed for operation on either alternating or high or low direct current The two-position machine includes an automatic switch which cuts out the motor, but leaves in circuit a high-resistance clutch, or holding coil, which retains the arm in the " off " position until the main circuit is broken

A considerable use has been made of the two-position machine for operating existing semaphore signals which are too far away from the cabin to be worked satisfactorily by mechanical means There has been a considerable field of development in the operation by battery power of distant signals In this case the machine is generally mounted at the foot of the post and operates through a crank directly on to the usual operating rod

Similar machines are often supplied for mounting at the top of the post, in which case the blade and spectacle, whether upper or lower quadrant, are bolted directly on to the spindle of the machine When the hold-off coils are released the signal goes to danger without turning back the gearing through which it is driven, and to provide against undue shock a dashpot is built into the machine

The three-position machine includes an internal circuit controller for cutting out the motor, and cutting in the clutch coils or slot, and for controlling external circuits for indication and repeater signals, or any desired scheme of wiring This arrangement obviates the necessity for an external circuit breaker operated by the semaphore arm When current is cut off, the arm returns to the " danger " position by gravity, and in so doing rotates the gearing and motor backwards Advantage is taken of this backward movement to run the motor as a generator and discharge current through a suitable resistance, so as to provide a braking effect in order to prevent shock to the mechanism

The ground signals consist of the same mechanism mounted in suitable cases, and fitted with discs or small arms

Train Stops —A mechanism similar to that of the two-position signal is used for operating the train stop, or trip arm This (fig 232) consists of a pivoted arm mounted alongside the running rail, and operated by the mechanism in conjunction with a signal, so that when the signal arm is at " danger " the trip arm is raised In this position it will engage with the trip cock connected to the brake pipe of the train, so that should the train overrun the signal, the brakes are immediately applied with full " emergency " force

Light Signals —The electric signalling system also includes light signals for railways both underground and in the open For underground

work lamp signals are installed, in some cases with a direct current, and in others with an alternating-current supply There are various types of lamp signals, the most interesting being perhaps the "flux neutralizer" signal which has no moving parts In this signal current is always in connection with the red lamp, but is suppressed when current is applied to the green lamp

Sykes' Electro-mechanical System —In this system the ordinary manual lever frame for working the points is retained, and a miniature frame for operating the signals is placed over it Such an arrangement saves a considerable amount of room, as the point levers may be spaced at 5¼-in centres, and the signal slides at 2⅝-in centres As far as possible the slides operating the signals are placed over the levers working the

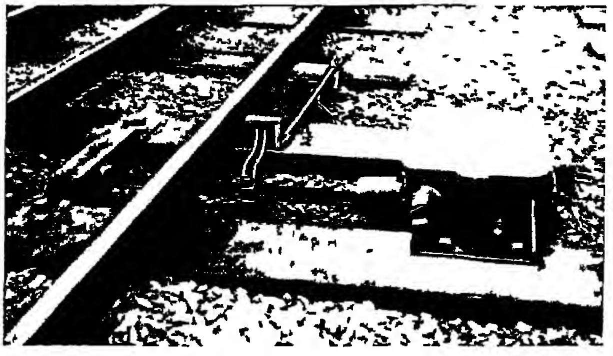


Fig 232 —Westinghouse Electric Train Stop

points which are governed by those signals, this saves the signalman much walking about

Fig 233 is a cross-section of the apparatus in the signal cabin The interlocking between signal slides is done on the shelf, and the interlocking between the signal slides and the point levers is done in the locking box at floor level A vertical shaft, which rotates in bearings, communicates the movements of the signal slide to the corresponding tappet placed in the locking box

The point tappets, which are actuated by a rack-and-pinion escapement gear, are placed on edge, contrary to the usual practice This arrangement is used on account of the close centres of the signal tappets, viz 2⅝ in All locks are loose, not riveted to the bars, and are moved by means of lugs welded on to the bars

It will be noticed that the casing over the slides is divided in the centre to form a box, this is for the purpose of containing the wires The contact springs for closing the signal circuits are mounted upon the wire boxing, and the contact block is carried upon a fibre insulating piece fixed to the slide in such a position that it joins up the two springs when the slide is pulled

An electric lock is provided for detection and check-locking purposes, the circuit of which passes through a contact fixed under the handle of the slide Before the slide can be moved, a knob at the top of the handle has

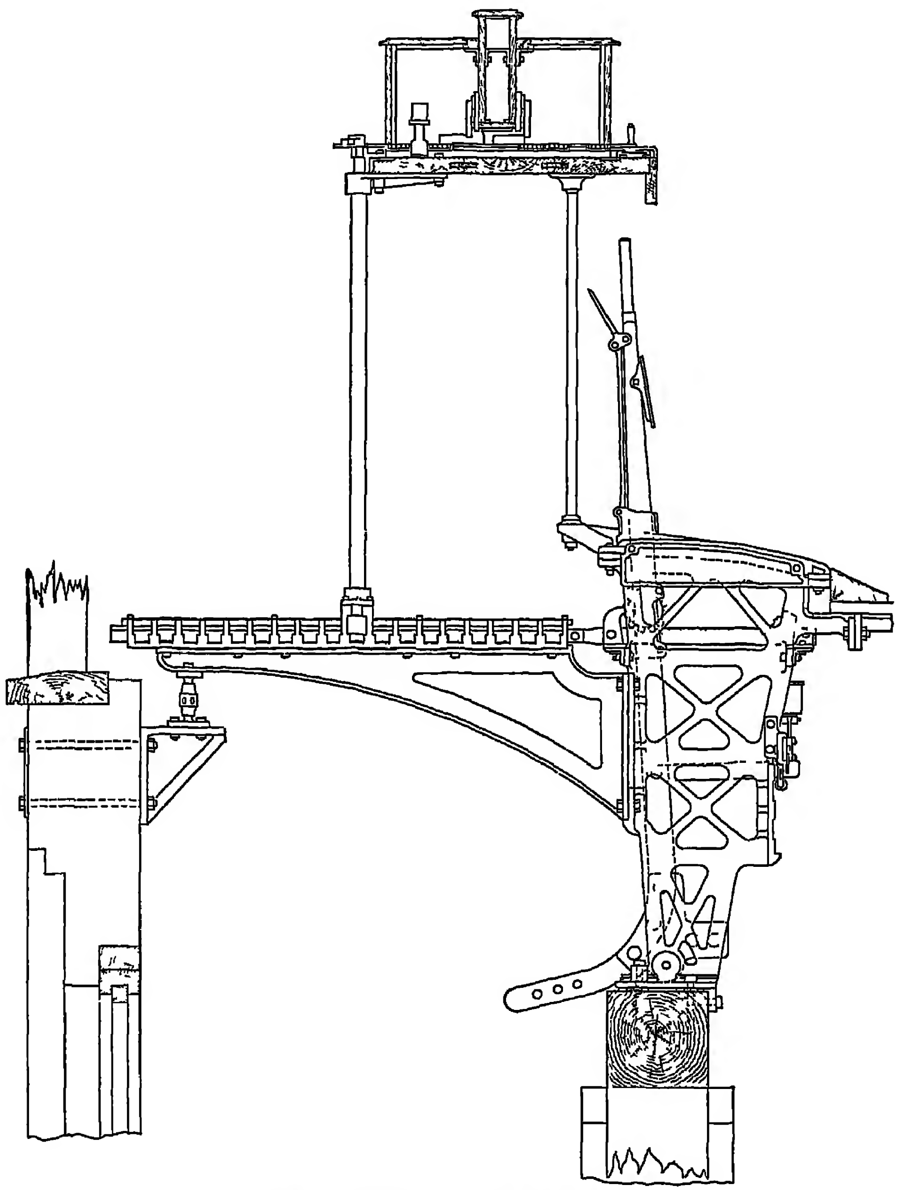


Fig 233 —Sykes' Electro-mechanical System

to be depressed by the thumb in order to remove a block from a notch in a plate (corresponding to the floor plate or quadrant of a manual frame), this also closes the above-mentioned contact

Engraved brass plates are provided for the number, description, and

releasing numbers They are all separate, the description plates being placed immediately behind the slides, and the releasing plates on the front board below The front board also carries the ringing keys and block plungers

In the lower part of the cabin a fuse board is fixed, through which each signal circuit passes, it also forms a convenient test box A common return wire is placed in each main run of wires, afterwards terminating in a return board, also in the lower part of the cabin, one return wire being taken from thence to the power house

From the fuse board the wires are run in insulated pipes, with inspection boxes at frequent intervals, to the signal motors, and then threaded through the point and bolt detectors to the common return (These appliances are described on p 233)

The signal motor is the same as that described on p 180, but in cases where a saving of levers is a consideration, a route indicator is used The arm is worked from the motor, and the numbers exhibited by a pair of coils and a selection device in circuit with the points over which the signal leads

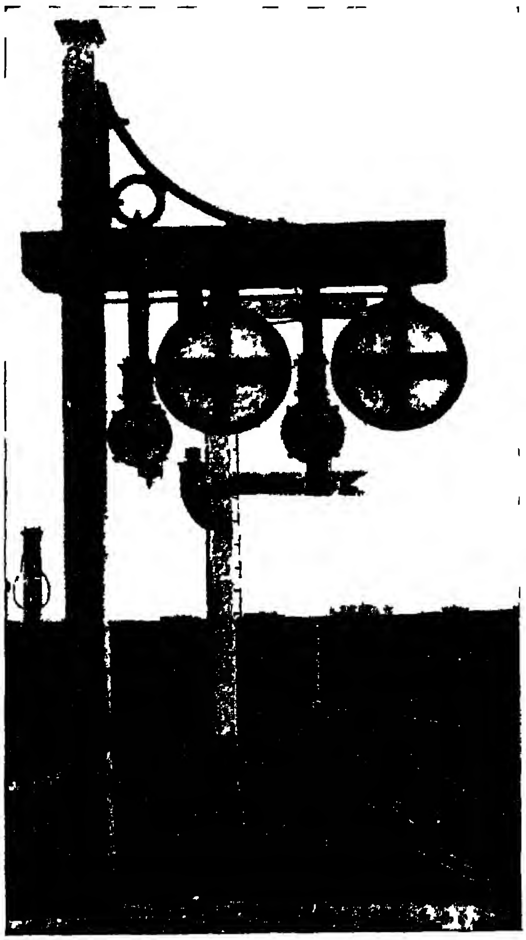


Fig 234—Banner Signal

There are many instances where a semaphore arm cannot be used, and in such cases the banner signal shown in fig 234 is to be recommended The arm is simply a light wire framework with a red fabric stretched over it It is balanced in the centre, and operated by means of a pair of coils and a Z armature At the back of the case a pane of opal glass is fixed, which is illuminated at night-time by a lamp. The front glass is, of course, plain The ground signal is similar in construction to the above, with the exception of the operating gear, which is in this case placed in a compartment in the base Two rods transmit the motion from the coils to the arm, which is balanced to fall either to the right or left, according to the road which is set

Messrs Sykes also manufacture a combined banner signal and route indicator similar to that for a semaphore arm, with the difference that the numbers are enclosed in the same case as the arm

The power used in the installation is derived from accumulators Two sets of thirty-two cells each are placed in the power house, one set always being in reserve Charging current is obtained from the local public supply The size of the cells depends upon the number of signals to be worked For instance, 300-amp -hr -capacity size has been found sufficient for 250 signals, and lasts on an average three weeks on one charge at a cost of 12*s* at 1*d* per unit

Installations of this system are to be found at St Enoch Station, Glasgow, on the London Midland and Scottish Railway, on the Southern Railway at Victoria Station (Brighton section), and at Grove Park and Folkestone on the South-Eastern section

Of recent years electro-mechanical installations constructed on very much the same lines as the Sykes system have been installed extensively in the United States

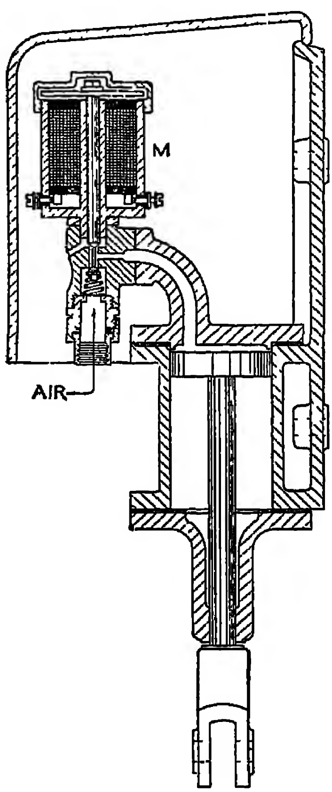


Fig 235 —Section of Westinghouse E -P Signal Motor

Westinghouse Electro-pneumatic System.—The power frame used in this system is the same as that used for the electric system described on p 174

Fig 235 is a diagrammatic section of a signal motor It has a diameter of 3 in , with a stroke of 4 in The compressed air, which is controlled by the electric pin-valve, is admitted by the pipe, as shown by the arrow Normally, the pin-valve is held up against its seating by the air pressure When the electromagnet is energized the valve is opened, and air is allowed to enter the cylinder, thereby pushing down the piston, and so lowering the signal arm Directly the current is cut off, the pin-valve closes and shuts off the pressure, at the same time opening the exhaust port, which allows the air to escape and the arm to go to danger by gravity

A pneumatic motor for a three-position semaphore arm is now being adopted It consists of two cylinders, each controlled by an electro-magnet pin valve, one cylinder operating the arm to the 45° position, and the other to the 90° position A special feature of this apparatus is that the air supply for the " 90° " cylinder is obtained through the " 45° " cylinder pin valve, so that the latter must be first operated before air can be admitted to the former This machine is likewise fitted with internal circuit-controller

The point motor is similar in construction, but is of course double-

acting, necessitating the use of two electromagnetic pin-valves and a slide-valve It is diagrammatically shown in section in fig 236 At all facing points an escapement gear is used in conjunction with a 5-in diameter motor having an 8-in stroke, this is quite sufficient to operate the facing-point lock, locking bar, and points

The trailing-point motor is 4 in diameter with $4\frac{1}{2}$ in stroke All points and plunger bolts are electrically detected The quantity of electricity required for the operation of the electromagnets is very small, a current of 0 05 amp at a pressure of 12 volts being sufficient for their certain operation It can therefore be quite conveniently furnished by a battery of six or seven accumulators, but in small installations ordinary primary batteries would suffice

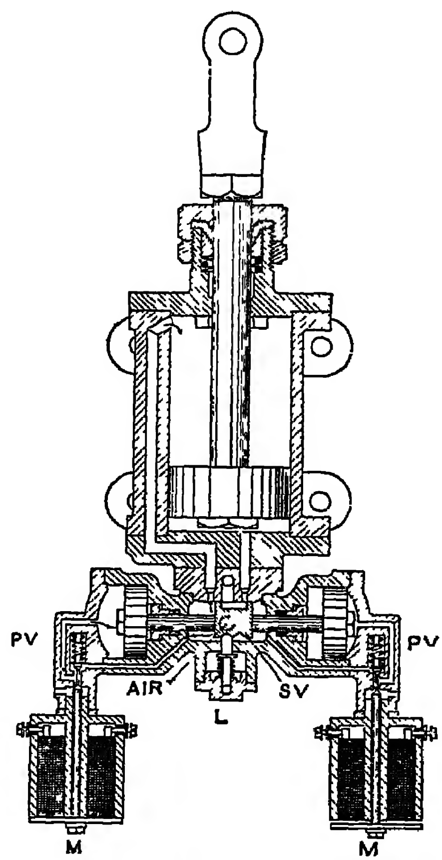


Fig 236—Westinghouse E-P Point Motor

In some installations it has been found more convenient to detach the electromagnetic pin valves from the point motor, and in these cases the valves are mounted on a special bracket located in a convenient position alongside the track

The latest type of apparatus is the "cut-off" type of point valve In addition to the normal and reverse operating valve another electromagnetic pin valve is added, which operates through suitable mechanism to lock the pin valves in the position they were last operated to, and cuts off the main supply of air to the point motor, thus eliminating waste of air which may otherwise be continually blowing past either one or both the point-motor pistons This valve is also mounted alongside the track Electro-pneumatic train stops are also included in this system

Low-pressure Pneumatic System.—The motive force used in this system is air at a pressure of 15 lb per square inch, whilst the controlling force, i e the force used to operate the relay valves admitting air to the motors, is air at a pressure of 7 lb per square inch The chief advantage of this low pressure is that trouble due to condensation of moisture is eliminated Leaks are also less frequent than with a high-pressure system All of the operating and indicating pipes are normally subject to atmospheric pressure only, compressed air being only admitted when a signal or point

is to be moved Check locking is provided on all levers, but the slight delay attendant upon its use is obviated by the levers being automatically moved the last portion of the stroke by the air, which gives the indication that the motor has responded to the lever

Fig 237 shows the piping and apparatus required for a semaphore signal The lever in the signal cabin is in its normal position, and pressure is admitted to the upper portion of the signal cylinder by means of the pipe *n* and port B The lever is now pulled for the whole length of its stroke By this movement L^2 is moved, admitting air at the lower pressure from the supply X through the reducing valve V to pipe *a*, which actuates valve R^3 and supplies air at the higher pressure to the lower portion of the cylinder A^2, pushes up the piston, and thereby lowers the signal It should be stated here that directly the piston moves, the port B is closed To restore it to the normal or danger position, L is pushed to the right until it is stopped by the piston rod of I coming into contact with the end of the

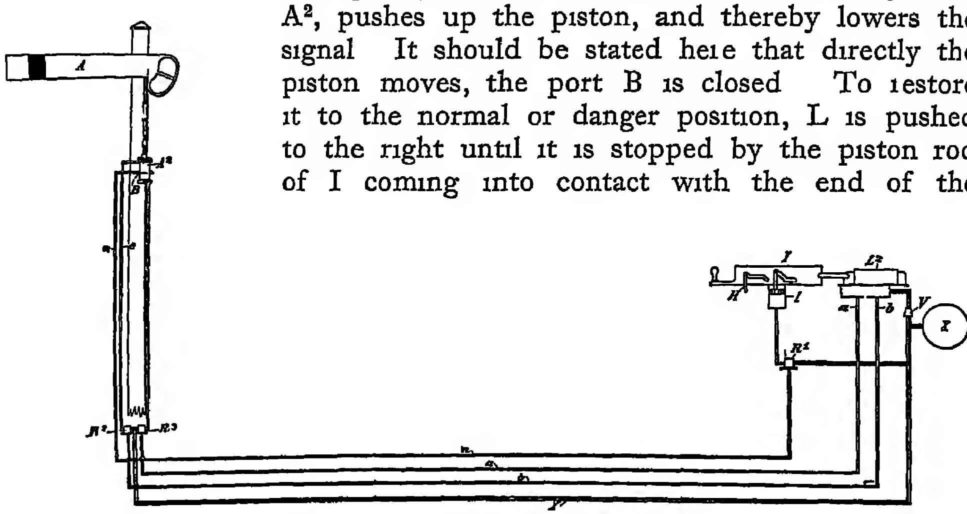


Fig 237 —Low-pressure Pneumatic System

horizontal slot in L The pipe *a* is now exhausted, pipe *b* charged, and valve R^2 is opened, which admits air from the supply through pipe *e* to the upper end of A^2, and so restores the signal The piston in descending discloses port B, allowing air to pass from *e* through B and *n* to R^1, and the latter causes air to enter I and complete the return stroke of the lever L by the action of the piston rod on the inclined portion of the slot

Where it is possible to work more than one signal by a lever, a selector valve is used It is placed at the points and worked off the motion plate similar to the ordinary point indicating valve, with the exception that it is provided with extra ports, and in one position of the motion plate the low-pressure operating pipe A (fig 238) is connected by means of the extra ports, with a low-pressure pipe operating the diaphragm for No 1 signal When the points are reversed, the pipe A is connected with the pipe operating the diaphragm for No 2 signal

Fig 238 is a diagram of the piping, valves, cylinders, &c When the lever in the cabin is pulled, air is admitted to the pipe A, it travels through the selector valve, as shown by the dotted line, to the diaphragm and valve

No 1, so admitting high-pressure air to the operating cylinder of No 1 signal When the lever is replaced, pipe A is exhausted, and low-pressure air admitted by pipe B to the diaphragm 1*a*, so admitting high-pressure air to cylinder 1, and putting the signal to danger This being done, the air is free to go through the indication valve 1, through cylinder 2, indication valve 2, and back to the cabin to complete the stroke of the lever The object of making the indication pipe go through both cylinders in series is to ensure that both signals are at danger before getting the indication

The point movement is shown in fig 239 When the lever is pulled, air is admitted to pipe *a* and valve R^5, which admits air at a higher pressure from the main X to the left-hand end of the cylinder C, pushing the piston to the right The points are operated, but the full stroke of the lever cannot be made until the pipes V and Y are connected by valve D, the relay valve R^3 operated, and air admitted to cylinder I^2, thereby completing the stroke automatically

Signalling at Glasgow Central Station (L M S , Caledonian section) —The Glasgow Central Station and lines approaching it on the Clyde Bridge have been equipped with the Westinghouse electro-pneumatic system already described The signal cabin is fixed on girders over the river, between the old and new bridges, a position which would have been quite unsuitable for a box equipped with an ordinary mechanical sig-

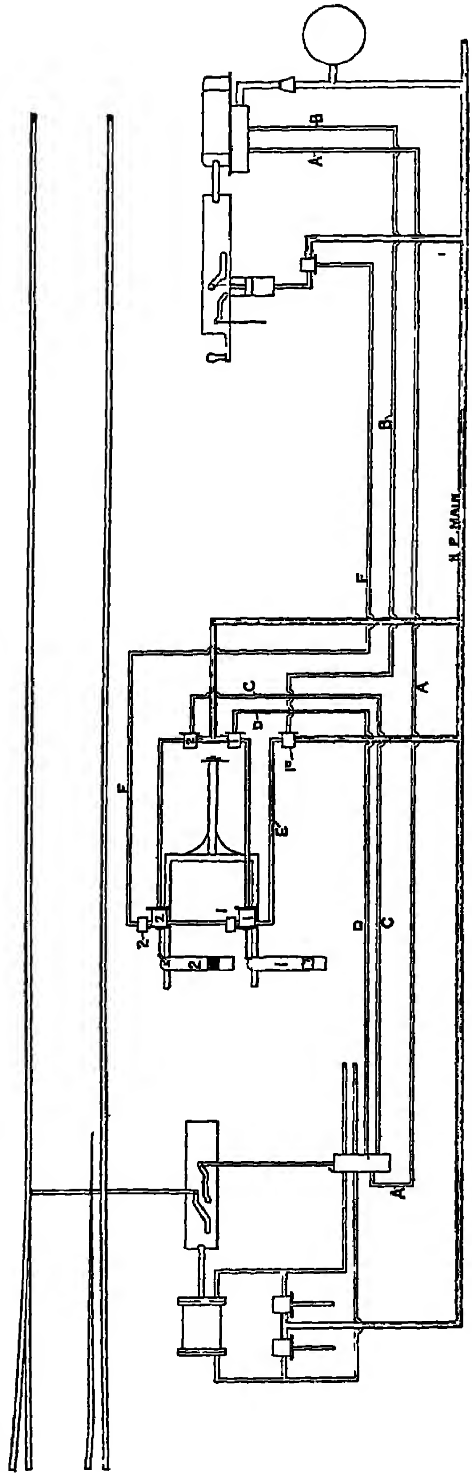


Fig 238 —Piping Valves, and Cylinder Arrangement for Low-pressure Pneumatic System

nalling frame Tyer's block instruments are in use, and a complete system of route-indicating and platform-indicating apparatus is installed,

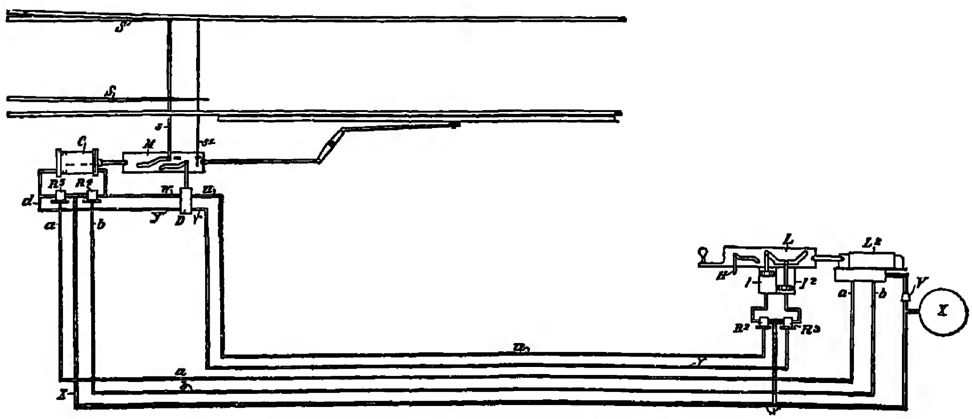


Fig 239—Point Movement in Low-pressure Pneumatic System

the latter working in conjunction with small supervising or look-out cabins inside the station itself, as track circuiting is not in operation

The cabin is 106 ft long by 16 ft wide, and has two stories, the inter-

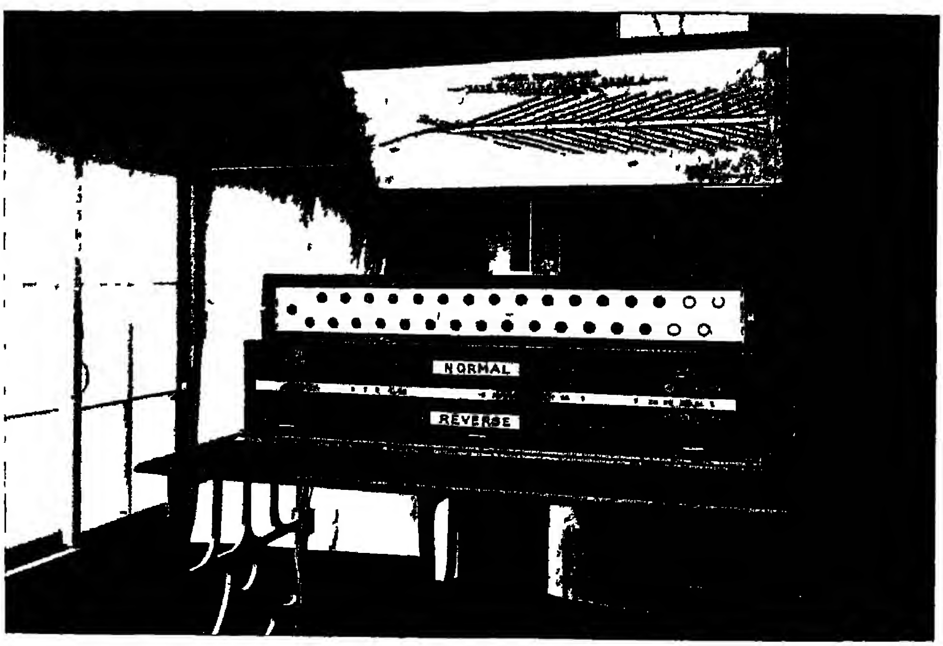


Fig 240—Push-button Machine

locking frame being 82 ft 6 in long and containing 337 levers and 37 spare spaces The levers are placed at 2½-in centres, being grouped in such a way as to afford the greatest convenience in working

There are 137 sets of points in the installation, and these, together with

the large number of signals required, necessitate several hundred compressed-air motors for their operation The main air line is carried along both sides of the plant and across the end of the station

The signals are for the most part carried on gantries across the lines so as to bring each one over the line to which it applies, and in order to avoid a multiplicity of arms route indicators have been extensively employed These have given great satisfaction

Fig 241 illustrates the whole lay-out, and is a typical case of what can be accomplished by modern power-signalling systems, this installation being one of the largest in Great Britain

Signalling Gravity and Hump Yards.—In large shunting yards, where gravity shunting is done, and the points have to be operated very quickly, a push-button machine is used as shown in fig 240, which is for low-pressure pneumatic operation of the points

When the buttons in the top row are pressed in they move out the corresponding lower buttons, and vice versa The action of pressing a button simply closes a contact governing the electromagnetic valve admitting air to the point cylinders Facing-point locks and bars are of course not provided, but a short length of track circuit between the fouling point and the signal is fixed instead When this section is occupied it is indicated by a small disc in the push-button machine just above the button controlling these points

Another method of working points has recently been installed at Feltham Hump Yard on the Southern Railway (South-Western section) A flat control table with a diagram of the yard on it has at the different points push buttons coloured white and red and coloured electric lamps The push buttons, two of which are provided for each pair of points, when pressed close the necessary circuits which cause current to operate Siemens point motors at the points One button causes the points to move in one direction and the other button causes movement in the reverse direction A yellow lamp shows whether the points are properly over, and the depressed button indicates the way they are set Should the points not be properly set, no yellow light is shown

To indicate whether the track including the points is occupied or not, track circuits are provided which cause a red or green lamp to light on the diagram according to whether the track has wagons on it or is free

MDM or Aster Route-lever System —This system is in extensive use in France on the Nord Railway Originally a hydro-pneumatic system, it has been developed as an all-electric system The selection of routes is accomplished mechanically in the locking frame by a simple cam and slide-bar system, the cams, operated by the route levers, driving the slide bars in groups and locking them according to requirements The control circuits for the points are governed by the slide bars Constant detection and track-circuit locking are provided

Other Route-lever Systems —There are several systems in use, especially in France, but space does not permit of their being dealt with

French signalling and traffic working lends itself readily to route working owing to the absence of shunting signals and the common use of one stop signal for several routes

A. E. G. (Berlin) Automatic Route-lever System.—This has been introduced for gravity yards and enables them to be worked with great facility The general principle is made clear in fig 242 The signalman in the hump cabin has an apparatus which has a series of plungers on it, one applying to each road in the yard As the vehicles come over the hump he depresses the plunger applying to the road required The first vehicle is, for example, going to road No 1, the second to road No 5, and both plungers have been actuated The route to No 1 is automatically established while that to No 5 is prepared in the cabin apparatus Directly the first wagon clears a treadle contact and insulated rail at point X (the

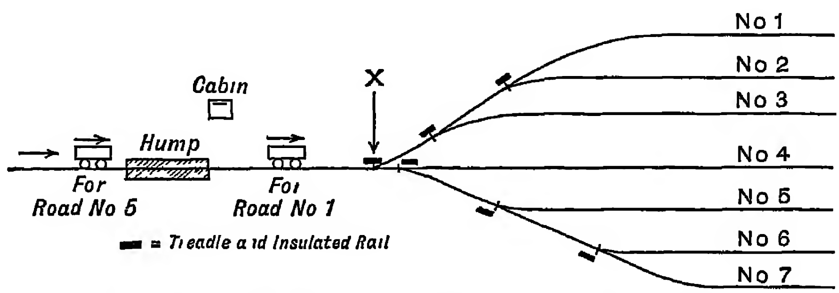


Fig 242 —Principle of A E G Automatic Gravity Yard Route System

clearing point of the two routes), the route to No 5 is immediately set automatically for the following wagon, and so on The signalman has simply to depress a plunger for each movement and can do so while previous movements are in progress, up to a certain limit The working is entirely electrical

Low-voltage Point Machines—With the greatly increased distance allowed by the Ministry of Transport for the operation of facing and trailing points, a demand has arisen in Great Britain for some means of moving them other than by the efforts of a signalman

The problem has been solved by the design of a point-moving mechanism, worked by a small direct-current electric motor requiring 5 to 3 amp at 20 volts to work it The necessary electric power is furnished by portable accumulators or large primary cells of some kind

In some of the installations, of which a few have already been put in, track circuits take the place of facing-point lock bars, and so save the motor this additional load The sequence of operations, which takes from 15 to 20 seconds, is first, the facing-point bolt is withdrawn and at the same time the electric detection contacts are broken at the first movement of the bolt, secondly the points move over, and thirdly the bolt is re-inserted into the stretcher blade, and the detection contacts are re-established There are also detection contacts connected to the point tongues This

detection ensures that the signals cannot be pulled off unless the points are correctly set

There are installations in Great Britain, at Ashington Colliery, a private line, on the London and North-Eastern Railway at Quainton Road, and on the Great Western Railway at Beaconsfield, Gerrards Cross, and Buildwas There is every likelihood of many more of these appliances being introduced at places where they can enable signal boxes or ground frames to be dispensed with

Light Signals.—The modern light signal is being introduced in place of power-operated semaphore arms The earliest light signal is by tradition reported to have been a candle burning in the window of a point watchman's house, it having been agreed with the drivers that the presence of a light meant that he was to stop

With the advent of the disc, cross-bar, and then semaphore for the daylight signal, it became simultaneously necessary to provide a night signal Generally coloured lights were adopted, and nowadays on most main lines in Great Britain two colours, viz red for "stop" and green for "proceed" at stop signals, and red for "caution, be prepared to stop at next signal" in the case of distant signals, the green indication being the same, viz "proceed", have been adopted (Reference should be made also to Chapter III)

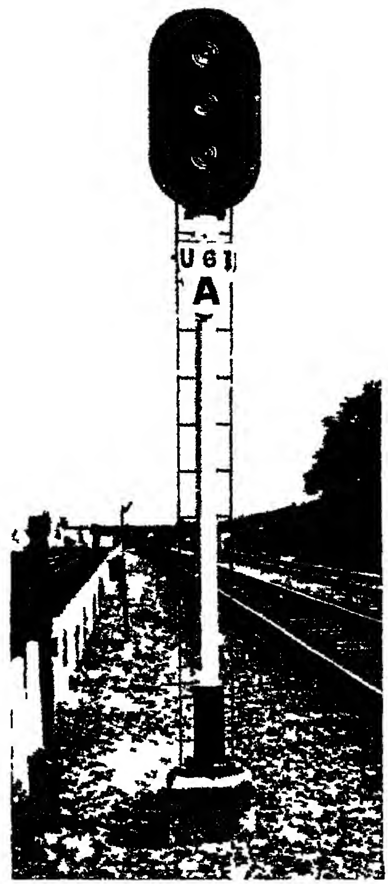


Fig 243 —Westinghouse 3-Aspect Day Colour-light Signal

To remove the inconsistency of running by a red light on a distant signal, some engineers have introduced a yellow light for "caution",[1] and the red light at the distant signal has been dispensed with

Between Paddington and Southall on the main line of the Great Western Railway the yellow distant signal night indication is provided Incidentally it is of interest to note that the semaphore arm has been painted yellow with a black band for these signals

On a stretch of line on the Great Central section of the London and North-Eastern Railway trials have been made with this colour for distant signal night indications, and on the Great Northern section it has been adopted throughout

The simplicity of the colour light signal has led to the successful

[1] This is now a requirement of the Ministry of Transport See Appendix

development of a similar indication for bright daylight This signal is known as the day colour-light signal, and has only recently been introduced into Great Britain from the United States An installation of these signals on an open steam-operated main line railway will be found between Marylebone and Neasden on the Great Central section of the London and North-Eastern Railway The Liverpool Overhead Railway, an electrically operated suburban system, is also signalled by this means, besides a section of the Metropolitan Railway near Harrow

There are a number of types of day colour-light signals, but all use electric lamps The power and type of these lamps vary

The simplest form of this signal is a sheet-iron box with upper and lower compartments, in which is placed a 220-volt 60-watt metal filament lamp A plain clear glass lens is provided, and a sheet of glass of the desired colour is placed between the lens and the lamp The interiors of the lamp compartments are painted white A relay is provided which is so controlled that when de-energized a red or yellow light is given, and when energized a green light is shown It is usual to place the cautionary signal in the lower position

Such signals are suitable for terminal and other large stations where an ample supply of electricity is available

These lamps can be repeated by running another suitable lamp in series with them, the second lamp being placed in the signal box To prevent failures due to the filament breaking, it is usual to change the lamps for new ones every 700 hours Another method is to underrun them slightly, thus 230-volt lamps would be used on a 220-volt supply In situations where vibration is considerable and the power question is not important, carbon filament lamps may be used with advantage

The modern development of the day colour-light signal is exemplified in the Hall light signal (fig 244) and the Westinghouse light signal (fig 243)

The Hall light signal, which comes from the United States, consists of a circular hollow casting suspended from a bracket by a ball-and-socket joint at the point of balance at the top of casting In the interior is fitted a specially designed reflector, at the correct point in which is placed a 3-watt or 10-watt 6-volt metal filament, double filament pipless lamp The reflector is so designed that the beam meets at a focal point about midway in the interior of the case, and at this point is placed an electrically moved vane carrying roundels of coloured glass about the size of a penny The light passing through this roundel has extracted from it all the colours except those required, and these pass forward to a special 10½-in diameter lens with a half toric formation The interior is accessible through a water-tight hinged cover on the under side of the casting This lens throws an almost parallel beam of unusual strength visible more than three-quarters of a mile away under conditions of bright sunshine with a 10-watt lamp in use The lens is usually hooded To change the colour the vane carrying the roundels is rocked either to right or left of the centre position

For curves and to enable the indication to be seen from a position im-

mediately under the signal, spreader lenses are provided Some of these signals are in use on the London and North-Eastern Railway at Wembley (Exhibition) Station

In the event of the main filament breaking, a series relay in the signal automatically puts the second filament into circuit, but at the same time an indicator in the signal box shows that the lamp is " wrong "

These signals can be and are run off primary cells or portable secondary cells, as well as from alternating-current supply systems through transformers

The Westinghouse day light signal consists of a separate compartment

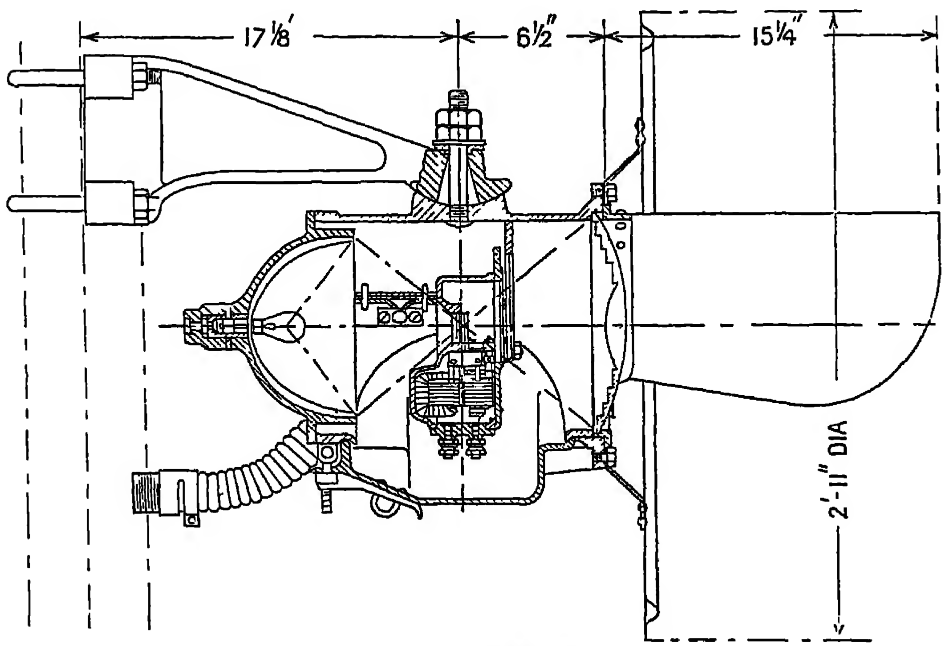


Fig 244—Hall Light Signal

for each coloured indication 4-in coloured lenses are employed of the Fresnel type, and two lamps behind each lens having different alternating-current voltage values

Westinghouse signals are employed on the Liverpool Overhead Railway, and the three-position type can be seen on the London and North-Eastern Railway, on the main line between Marylebone and Neasden

Another type of day light signal is of the position-light type, which is extensively installed on the Pennsylvania Railroad in the United States

In this signal rows of pale-yellow lights, three in each row, give the aspect required A horizontal row means " stop ", an inclined row " caution ", and a vertical row " proceed "

The whole mechanism is mounted behind a black circular disc through which the rows of lamps show.

This signal possesses the advantage that the increased power required to get a strong coloured light is not necessary, the yellow-tinted lens giving out a strong light in bright daylight at the expenditure of considerably less power In addition the signal has the same appearance by day or night, and it is not necessary to distinguish colours in order to read the indications

It is necessary to dim the lamps at night in some cases, owing to the drivers being dazzled by them

---

CHAPTER XII

Signalling in Fog and Falling Snow

The problem of conveying the signalman's message to the driver when the state of the atmosphere is such that the signals cannot be seen, has been solved on electrically-operated railways, but on the steam-operated lines the system which is used, while ensuring safety of the trains, does not prevent delay

The method adopted on the electric railways is by fog-repeater and automatic train stop

On steam railways the detonator placed on the rail by a fogman and exploded by the train to be signalled is adopted, together with special method of block working On a few lines there is partial provision of automatic train control, or cab signalling

The details of the two systems are as follows

Fog-repeater and Automatic Train Stop on Electric Railways—The employment of fog-signalmen has been eliminated on some electric railways by the use of fog-repeaters, which are special supplementary visual signals brought into use in foggy weather to enable the driver to know the position of the ordinary signal some distance before reaching it The repeater consists of a case mounted on a post, as nearly as possible in the driver's direct line of vision, and containing two compartments, one fitted with a yellow and the other with a green lens An electric lamp preferably with concentrated filament is fixed behind each lens These repeaters are generally placed at distances varying from 200 to 66 yd in front of the signal to which they refer and work in sympathy with it, so that the yellow lens is illuminated when the signal is at "stop" and the green lens when it is at "proceed" They are controlled in groups by switches placed in the neighbouring signal boxes, the signalmen being responsible for bringing them into use when the state of the weather requires it Practice has shown that these repeaters are of great assistance to the drivers and much more satisfactory than the ordinary fog-signalling methods, enabling a very good train service to be run even in bad fogs To get the best results with fog-repeaters they should invariably be fixed

on the same side of the track (the left-hand side in England, where trains run left-handed), and the driver's place on the footplate should be on the same side The right-hand drive, used on many English lines, is very unsatisfactory from the signalling point of view, and it is hoped it will eventually be abandoned, as in France

An installation of fog-repeaters was made on the Brussels-Antwerp main line, Belgian State Railways, some time before the late war, but was removed by the Germans In this case each distant signal was preceded by three repeaters, and each home signal by two Each signal cabin was fitted with accumulators to provide against any interruption in the current supply, and the distant signals were operated by motors to allow of the accumulators being worked continuously This installation gave great satisfaction, and showed that fog-repeaters are suitable for main-line as well as suburban service The chief difficulties in the way of adopting the repeater are (1) the provision of a suitable source of energy, and (2) finding space for fixing, where there are parallel lines The former is of no importance on electric railways, but on steam lines would sometimes be expensive to carry out However, on sections where the traffic is sufficiently heavy to warrant fog-repeaters, it is probable that some source of electricity could be found in the district, of a private or municipal nature Where the 10-ft space does not exist between parallel lines, the fog-repeater cannot be fixed in the usual position, but this difficulty could probably be met by placing it low down between the tracks and tilting it slightly so as to project the beam of light upwards Experiments on these lines are being made outside the Paris terminus of the French Northern Railway A fog-repeater on a London electric railway is shown in fig 245

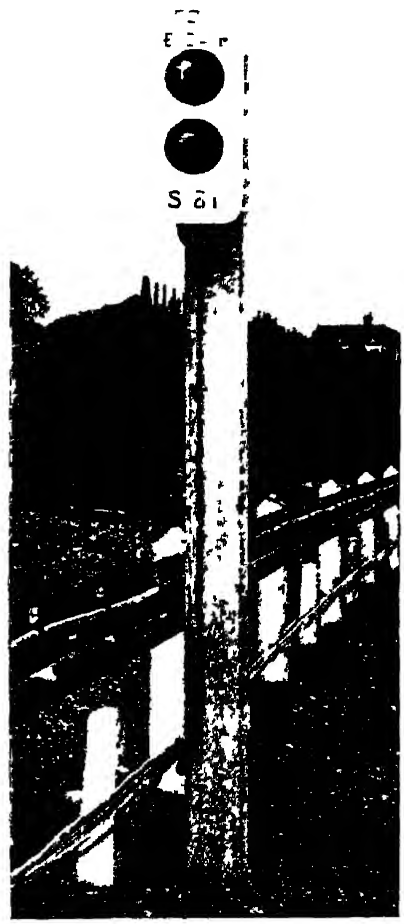


Fig 245—Fog repeater E & S B R

On the Belgian State Railways for many years distant signals have been provided with approach indicators, which are made of wood (fig 246) and fixed close to the line, to attract the driver's attention They are painted white Each signal is preceded by five indicators placed at 50-m.

intervals, the first one encountered having five black bars painted on it, the second four, and so on Experience shows that these indicators are of very great assistance to drivers, especially in foggy weather, when there is difficulty in finding the signals With the introduction of three-position signalling, the use of these indicators has been extended to cover all signals capable of repeating the indications of a following signal In a few cases enamelled plates are used instead of painted boards

It is the practice to use, with electrical fog-repeaters, a train stop which is placed alongside the "stop" signals The train stop consists of two parts, a hanging trigger on the leading bogie of the electric train, or on the locomotive in the case of a steam train, and a movable arm at the signal (fig 247) The trigger (which is of wrought iron), when it is forced on one side, is arranged to open a valve in the train pipe of the automatic brake system of the train In some cases the electric power can also be cut off from the train motors The movable arm on the permanent way stands upright and normally fouls the trigger by about 1½ in when its signal is at "stop" The head of the arm is 4 in wide Should the signal go to "proceed", the arm turns with the shaft to which it is attached, the head dropping to just below rail level The shaft is rotated by the power used for the signalling, viz either by electrical or pneumatic means

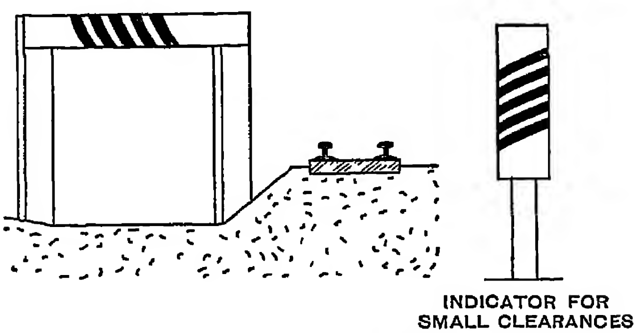


Fig 246—Belgian State Railways Distant Signal Indicators

An electric train stop arm (fig 248) made by Messrs Sykes Interlocking Company is shown It is mounted on the rail by means of three short bolts through the web of the rail, and two hook bolts underneath The arm is lowered by means of one of their Z armatures, a pair of contacts being broken at the end of the movement, thereby cutting in a high-resistance hold-off winding on the coils and reducing the current consumption A weight carries the arm to the upright position directly the current is cut off, and a lock drops behind the armature and secures it, thus preventing the arm from being pushed down by hand

Another type of train stop arm is made by the Westinghouse Brake and Saxby Signal Company This can be operated by a cylinder and piston with compressed air, or by an electric motor (fig 247) A spring is fitted to ensure the arm being upright in the normal or dead position

As the train stop arm is not controlled by the signal arm, it will resume the "stop" position should for any reason the signal arm not return to the "stop" position when it should do so

This system ensures a complete stop, as the driver has to get down on to the permanent way to reset the trigger on the motor bogie

Trains travelling up to 50 miles per hour are satisfactorily stopped by this device, which is entirely approved of by the drivers

Fog Signalling on Steam Railways—The aural or detonator system is generally in force on the main trunk lines of England

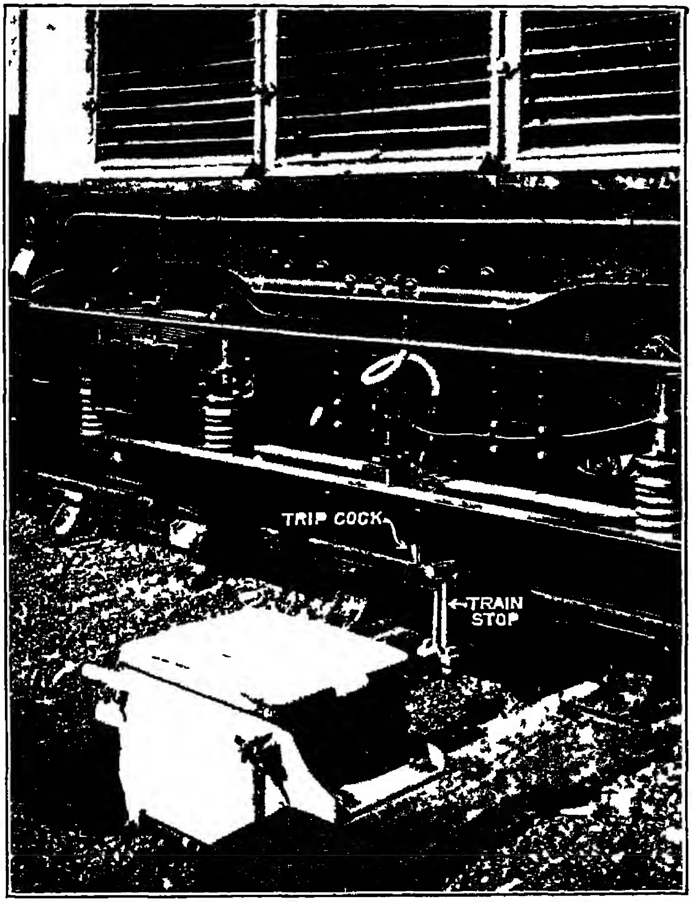
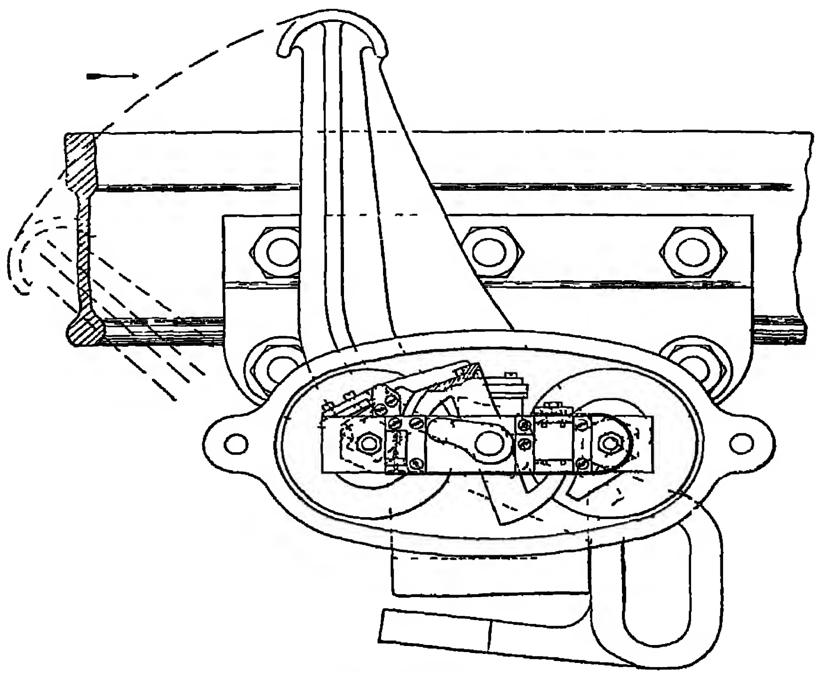


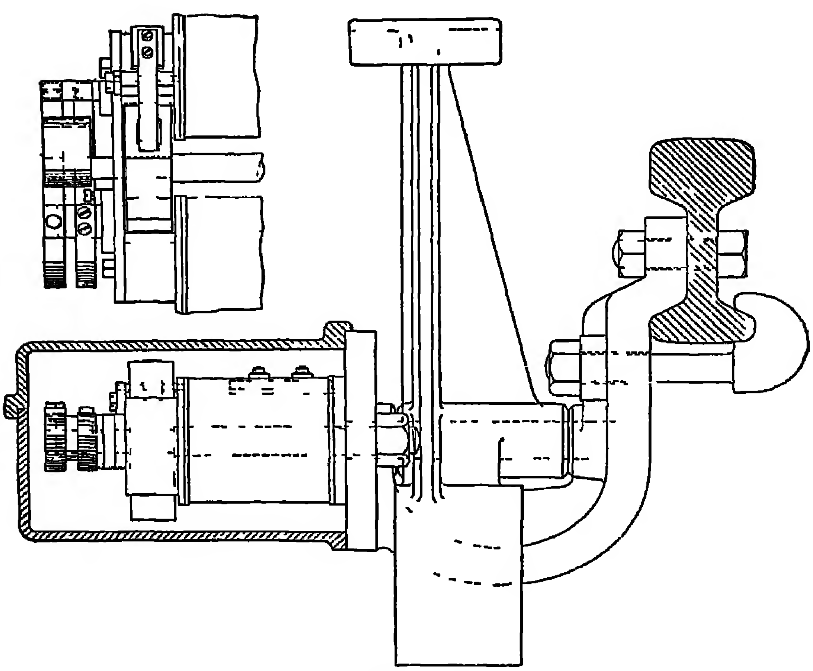
Fig 247—Train Stop

Before proceeding to describe the different forms of machines and apparatus designed to supplement the fixed signals during fogs and snowstorms, it is of interest to study the standard rules which should be observed at such times when the fixed signals are not clearly visible

The men who are selected for fog-signal duty are usually drawn from the platelaying gang, each man being appointed to a post, so that he may immediately proceed to his post when a fog comes on Before doing so, however, he must report himself to the stationmaster or signalman in charge of the post, who will enter the time in the train book and supply



Front Flevation



End Elevation

Fig 248 —Electric Train Stop Arm

him with a coat, lamp, flags, and the requisite number of detonators

The signalman should be responsible for calling out the fogmen, and must report any men who fail to attend or are not prompt in responding On most lines he must use his discretion, judging by the density of the fog or snowstorm, but on the old North-Eastern Railway a target with a cross painted upon it, showing a white light at night, is fixed at a distance of 170 yd from the signal cabin Directly this becomes invisible from the cabin the signalman is authorized to call out the fogmen

During the interval which elapses between the time the men are called out and the time they are booked on duty special arrangements must be adopted in connection with the signalling of trains, which are as follows A train must not be accepted from the rear signal cabin until the "train arrived" signal has been received from the cabin in advance This, however, will not apply at a junction where the facing points can be set in another direction, and a following train in such a case dealt with under the ordinary block telegraph regulations

As soon as the atmosphere clears sufficiently to enable the drivers to discern the signals within a reasonable distance there is no necessity for detonators to be placed on the rails, although the fogmen must continue on duty until called away

Fogmen must see that the signals are placed at danger behind each train, and that each train carries a tail lamp Should the signal not go to danger, detonators must be placed on the rail and the signalman communicated with immediately

It is the duty of the fogman to exhibit to the driver a light corresponding to the colour of the semaphore which is being fogged

When at signal cabins assisting signalmen, or working under the signalmen's instructions, fogmen must place detonators on the rail immediately after the passing of a train, whether instructed to do so or not, and when mechanical fogging machines are provided in connection with levers in the signal cabin the fogmen must frequently examine them and satisfy themselves that they are in proper working order

In cases of home and distant signals on the same post, the fogman must keep the detonators on the rail until both signals are lowered Great care must be exercised to ensure that the lead clips of the detonators grasp the rail firmly

Enginemen must exercise the greatest caution, especially when approaching junctions and important stations Should they fail to see the fogmen, or fail to obtain the "all-right" signal from them, they must treat such signal as being at danger, and act accordingly

The fogman's duty is very hazardous, owing to the danger in crossing the running lines to place detonators on another road In order to minimize the risk many appliances have been patented, one being the Clayton machine, which enables the man to stand in the most convenient place and fog his signals with perfect safety

The machine consists of a removable magazine, which holds about

forty detonators The magazine is fixed in a vertical position near to the arm of the machine in the six-foot way The arm rotates through a semicircle, and is actuated by means of a pinion wheel and a rack, which is connected by a length of rodding to the actuating lever At the end of the arm is a pair of jaws which grip the detonator

Fig 249—Sykes' Fog Pit Repeater

The operating lever is fixed outside the fogman's hut, and has three positions When in its normal position the arm is in the magazine, gripping a detonator, pulling the lever right over swings the arm through a semicircle and places the detonator on the rail If it is desired to remove it, owing to the signal being lowered, the lever is placed in the midway position, causing the arm to be moved to a position parallel to the line When a detonator is exploded, the lever is returned to its normal position, and the arm, in returning to the magazine, runs up a short ramp, causing the jaws to be separated and the spent detonator to be released by coming into contact with a hinged flap on the magazine

When the magazine is emptied the arm becomes locked, so that the lever cannot be operated All that now remains to be done is to take off the old and fix a new magazine—the work of a few seconds—and all is ready for work again

In order to repeat the semaphore arms of high signals, short arms are sometimes fixed near the foot of the post, or in cases where the signal is some distance away from the fogman's hut a miniature signal is erected behind the fog lever and is connected to the signal, which it repeats by means of a light rod Such arrangements, however, are very cumbersome and are liable to get out of order Cases have also been known where the complicated connections from a large group of signals have prevented the signal arm from going to danger It is now generally recognized that an electrical repeater is more suitable for this purpose, although it must be admitted that the usual type of repeater as used in the signal cabin is unsuited for the work owing to the condensation of moisture setting up rust on the pivots and causing it to stick Then, again, it often happens that the batteries are unattended during the summer months and consequently are liable to be out of order when a fog comes on suddenly

All of these difficulties are overcome in the apparatus shown in fig 249, which shows a Clayton lever with Messrs Sykes' electrical fog pit repeater in the rear The arm of the repeater is balanced in the centre and is worked by means of a pair of coils and a short laminated armature The whole of the mechanism is placed in a clear glass jar and immersed in a light mineral oil A lock-up cupboard contains the repeaters, and a peg switch is fitted just inside the door in such a position that it is impossible to shut the door until the peg is removed, thereby disconnecting the batteries

Another apparatus which has been successfully used on the North-Western section of the London Midland and Scottish Railway is illustrated by fig 250 This machine holds four detonators, one of which is shown on the rail ready for exploding The fogman, who controls the machine by means of a hand lever, will be noticed in the background A similar contrivance is operated from the signal cabin

On the Great Western Railway a fog-signalling machine is used by which the fogman can work the detonator from his position on the outside of the track to the running rail, even when the rail is four or more tracks away A passage way under the roads is provided in which are placed light guide rails and rods At the fogman's end and the running rail end are pulleys over which a continuous chain is passed, also at the running rail end the guide rails fork Attached to the chain is a slide which runs on the guide rails and rods To the slide are fastened two carriers in which the detonator tails are clipped When the fogman rotates the chain wheel the carriers are pushed or pulled along the guide rails, according to the direction of rotation of the operating wheel To put the detonator on the rail the carriers are wound out to their full extent

In connection with this machine, economizer plates are used By means of this device the explosion of the first detonator acts on a deflecting plate, causing the plate to rock an arm which snatches the second detonator off the rail before the wheel reaches it An important economy in detonators

is obtained in this way without diminishing the safeguard provided

There are many other types of fog-signalling machines in use upon different railways—some engineers preferring to work them by means

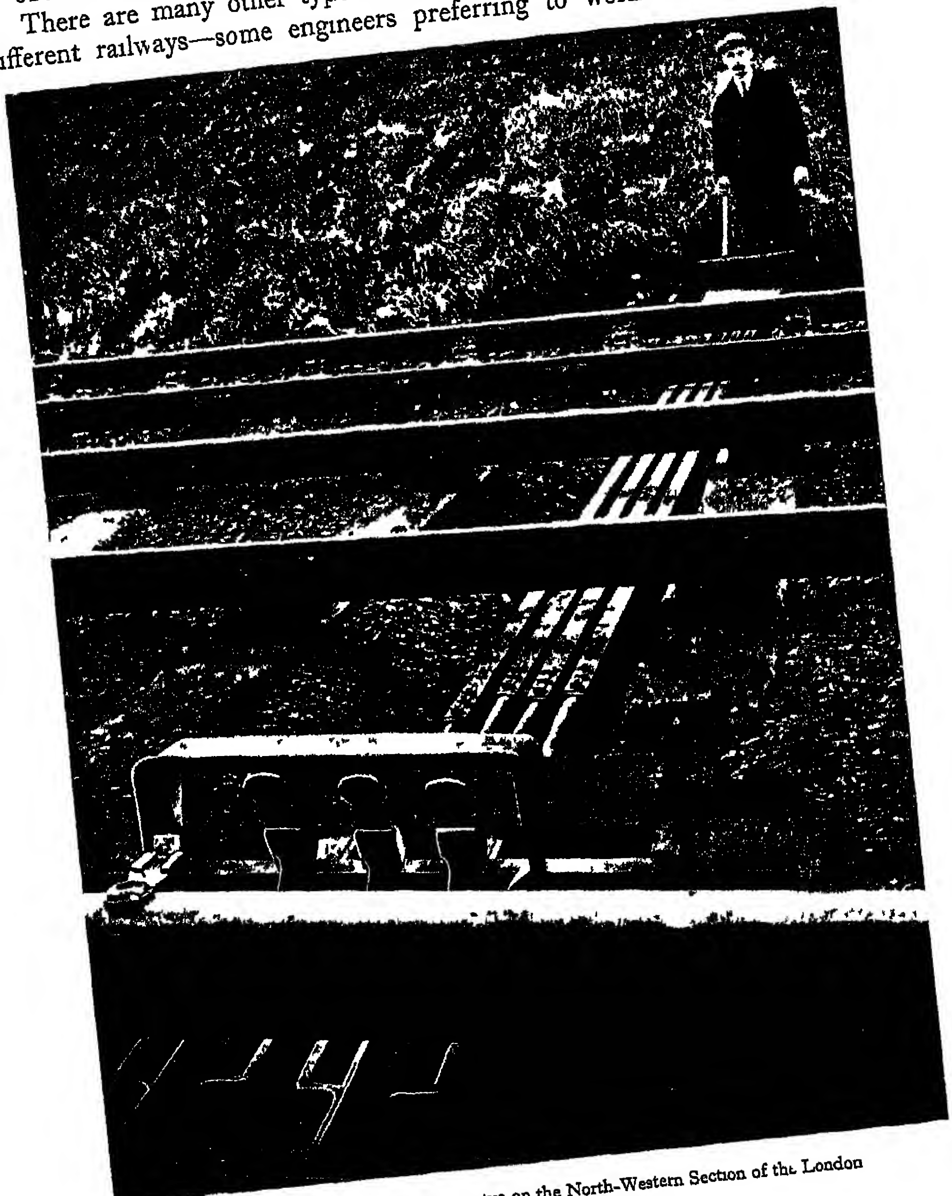


Fig 250—A Fog-signalling Apparatus on the North-Western Section of the London Midland and Scottish Railway

of a hand lever on the ground, others by a lever in the cabin, and others again couple them to the same wire which operates the signal On the Metropolitan District Railway the Clayton machines are actuated by means of an electro-pneumatic motor which is governed by the signal

Automatic Train Control—For many years signal engineers have been studying the problem of getting the signalman's message into the cab of the moving locomotive so that the driver can easily and accurately understand it. In addition, should the driver misunderstand or not notice it, then the brakes can be applied and the train brought to a stand.

The subject is of such importance that the Ministry of Transport recently appointed a committee to (*a*) Enumerate the possible functions of automatic train control in relation to railway conditions in the United Kingdom, and prescribe requisites which devices should fulfil. (*b*) To examine automatic train control devices under trial, and recommend for further trial or for experimental installation any devices which are or may become available during investigation. (*c*) To form conclusions on the adoption of automatic train control in respect of all or any of its possible functions, having regard to the advantages to be attained and the cost involved.

The committee, which was presided over by Colonel Sir J. W. Pringle, C.B., Chief Inspecting Officer of Railways, reported in 1923.

Amongst the seven recommendations they made there appear the following:

No. 1. They are of opinion, after careful examination and analysis of statistics during the past ten years, that automatic train control presents the only reliable method of preventing a large proportion of train accidents directly occasioned by failures of enginemen to obey signals, which amount to about one-third of the total.

No. 5. They are of opinion that a complete system of automatic train control should include a train-stop device at selected stop signals, and train control generally at distant signals. They are satisfied from their investigations, however, that control at stop signals is of first importance, as a means for providing additional security.

In the United States, owing to numbers of serious collisions, the Interstate Commerce Commission has ordered most of the railways to install some form of automatic train control, and one locomotive division on each railway has to be so equipped within a given period. The functions to be performed by the apparatus are laid down by the Interstate Commerce Commission.

In Great Britain the systems which are in use are the Great Western Railway system, the Reliostop system on the Great Central section of the London and North-Eastern Railway, the SYX system in use on the Ongar and Palace Gates branch of the Great Eastern section of the London and North-Eastern Railway, and the North-Eastern system in use on the North-Eastern section of the London and North-Eastern Railway. There are also a number of other devices in different stages of development.

As well as the additional safeguard provided by automatic train-control apparatus, it has been found by experience that trains suffer less delay in foggy weather when drawn by locomotives fitted with the apparatus.

Great Western Railway System.—This system gives the driver

information regarding the distant signal and through it, by implication, the position of the home signal ahead

It can also, if required, warn a driver to reduce speed where permanent speed restrictions are in force

The signals received on the locomotive are

Distant signal " off " An electric bell rings which was usually stopped by the driver, but it has now been arranged for a slow-acting relay to cause the bell to ring for about five seconds

Distant signal " on " An air siren operated by the inrushing air into the train pipe gives the warning signal If the siren is not stopped by the driver the brake application is sufficient to ensure the train being stopped before it reaches the home signal, even when steam is left on.

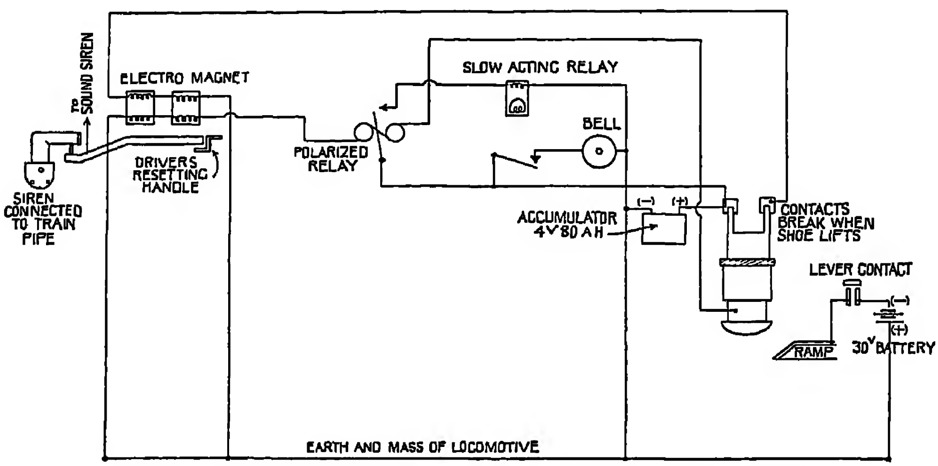


Fig 251 —Great Western Railway Automatic Train Control Electrical Diagram

The apparatus consists of two main parts the apparatus in the signal box and on the permanent way, and the apparatus on the locomotive

In the signal box a lever contact is attached to the distant signal lever, and a battery of primary cells giving about 30 volts is connected by this lever contact to insulated wire which runs to the ramp See fig 251, which is the electrical diagram

The ramp consists of an inverted T iron, 4 in by 2 in , which is mounted on a wooden insulating support, and varies in length from 40 to 60 ft It is fixed in the four-foot way very slightly askew of the centre line, and about 400 yd to the rear of the distant signal to which it applies, provided that signal is not the lower arm on a home signal post, when it is fixed immediately ahead of the signal The askew setting is done to prevent grooving of the shoe and assists in the removal of ice

On the locomotive the main parts are a sliding and lifting contact shoe (fig 252), an apparatus box containing a polarized relay, electromagnet, electric bell, and automatic steam switch, and thirdly, a 4-volt 80-amp -hr. accumulator. The sequence of operations is

(*a*) With the earlier apparatus, when the steam pressure was below a certain limit (40 lb per square inch), the circuit from the accumulator to the electromagnet was opened by a steam switch and the whole of the apparatus was dead

(*b*) As soon as steam was raised the automatic steam switch closed and the electromagnet was permanently energized

(*c*) If a distant signal is " on ", the ramp is not electrified as the distant signal lever has not been pulled The shoe on passing over the ramp lifts and opens the contacts attached to it, and causes the electromagnet armature

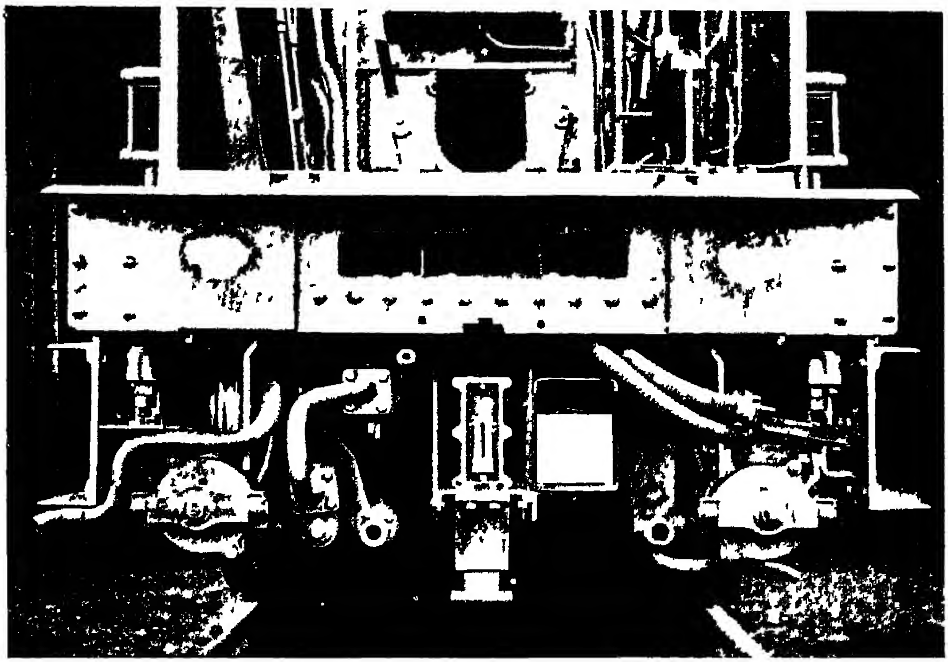


Fig 252*r*—Sliding and Lifting Contact Shoe on G W R Locomotive

to drop, which opens a valve into the train pipe The inrushing air sounds the siren, the brakes meanwhile being applied The driver can stop the siren and close the air valve by moving a lever which lifts the armature again up to the pole-tips of the electromagnet As the ramp has now been passed it is held up

(*d*) Should the distant signal be " off ", a current of the correct polarity is put on to the ramp When the shoe touches it and lifts, although the shoe contacts are opened, a current passes to the coils of the polarized relay which closes its contact, and continues through a separate winding on the electromagnet, preventing the release of the air valve The polarized relay contact closes the electric bell circuit, causing it to ring until stopped by the armature dropping on the slow-acting relay

It will be noticed that in the event of a failure of electricity either to the ramp or on the locomotive the " stop " indication is given

The whole of the apparatus is of robust construction, and has been in use for eighteen years. About 200 locomotives, including a good proportion of main-line express engines, are fitted with the apparatus.

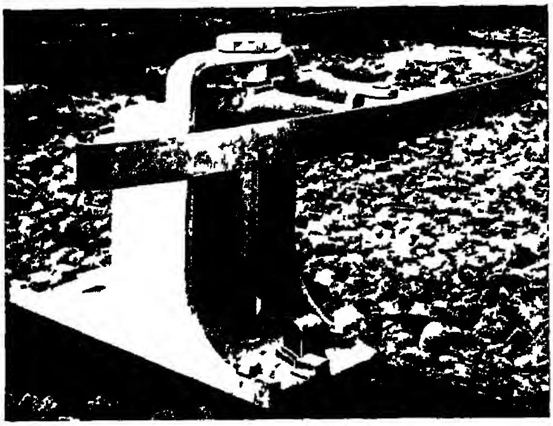


Fig. 253.—Warning Machine used in Reliostop System.

The main line between Reading and Paddington is equipped with the ramps, and experience has shown that locomotives fitted with the apparatus keep better time in fog than those not so fitted.

For working on single lines, use is made of the polarized feature of the relay, viz. the direction of the current on the up and down ramps being different.

Reliostop System.—This is a purely mechanical warning and stopping device, installed in the London territory of the Great Central section of the London and North-Eastern Railway. A number of large passenger tank engines are fitted with the travelling part of the mechanism. On the permanent way on the right-hand side of the running line are fixed (*a*) a "warning" machine (fig. 253) 300 yd. before a distant signal is passed, and (*b*) a "stop" machine (fig. 254) situated about 10 yd. ahead of home, starting, and advance starting signals.

Fig. 254.—Stop Machine used in Reliostop System.

The system works as follows. An engine on approaching a distant signal receives a warning, by a gentle application of the continuous brake, which the driver corrects immediately or otherwise according to the indications exhibited by the signals. The brake application is caused by a treadle trip on the engine (fig. 255) rubbing along the vertical face of a 3-ft. ramp forming part of the warning machine. The ramp is curved slightly towards the engine, thus causing the treadle trip to move also. This movement releases

an air inlet valve, which causes the equilibrium on an automatic air inlet relay valve to be destroyed, air rushing into the brake pipe through a siren, giving the driver an audible warning The driver can operate a " driver's valve ", and restore the air inlet valve which was opened by the movement of the treadle trips, and so free the brakes

Should the stop signal be " off " the stop machine is inoperative, as the movable member of the stop machine is pulled clear of the engine apparatus when the stop signal is pulled off

When the stop signal is " on ", the movable member, which consists of a horizontal arm or crank mounted on a vertical rotary shaft, stands approximately at right angles to the rails in the path of the trip device on the engine Should the stop signal be overrun the arm engages, as shown, with a ¾-in wooden prop on the engine apparatus The wooden prop is broken by the impact, causing the upper arm, which is a trip lever, to be released, and opening an air inlet valve into the braking system, causing a full application of the brakes

Fig 255 —Treadle Trip used in Reliostop System

The driver is unable to cancel this application until the engine has stopped and another wooden prop has been inserted between the upper and lower arms

It is also arranged by contacts on the stop machine for the operation of the arm to be repeated to the signalman, and in addition for a warning to be given should the apparatus be overrun or struck by out-of-gauge loads or hanging truck doors

Raven's Electrical System —This system, which is the invention of the late chief mechanical engineer of the old North-Eastern Railway, has been revised In its new form it has been in use some eight years, and has shown itself to be an improvement on the original system The apparatus has been designed to give the fullest possible indication of failure of the equipment The normal operating of the indications being by a continuous current, any interruption of it causes the danger indication to be given

The system consists of two main parts (*a*) the apparatus on the ground, viz in the signal box and between the running rails, (*b*) the apparatus on the locomotive The apparatus on the ground comprises contact bars between the running rails, lever contacts in the signal box, tapper keys, indicators, batteries, and wiring The engine apparatus is made up of polarized route-control relays moving miniature semaphore arms, bell relay, brake-controlling magnet, battery, bell, push, cut-off, contact brushes, and contact shoe with switch The indications given are visual and audible, with a brake application in addition The visual indications on the engine are miniature semaphore arms An indicator with two arms is provided so that junction routes can be given in the cab An electric bell in the cab, which can be stopped by the driver, is the audible indication

The brake control apparatus consists of a stop-cock electrically controlled by means of an electromagnet, which when energized holds up an armature connected to the stop-cock, and holds it in that position The action of lifting the armature to the coils is carried out by hand The stop-cock is inserted in the engine train pipe of any automatic braking system Should the magnet coils become de-energized the armature falls away therefrom by gravity, and the stop-cock is opened, causing an application of the brakes

The system operates as follows A split contact bar is installed well to the rear of the distant signal, so that a warning can be given that a signalled area is being approached A solid bar is next provided a little in advance of the distant signal and another midway towards the home signal, another at the home signal, and another at the starting and advance starting signals These bars, with the exception of the "warning" bar, are electrified by the signalman when he pulls the signals "off" The shoe on the locomotive is of special construction, one part only being touched by the warning bar, the space provided by the split in the bar preventing the part of the shoe controlling the brake gear to be operated

If the signals for a junction are "on", the sequence is

1 Indications go to "danger" and bell starts ringing at warning bar, and continues ringing until stopped by driver The miniature arms remaining at danger warn the driver that the home signals are "on"

2 On passing over the distant bar, he will receive, in addition to the bell, a brake application, which he can restore

3 At the intermediate bar he will again get the same indications

4 At the home signal he stops and stands on the bar Standing on the bar stops the bell, but enables the signalman by operating his tapper key to work the miniature semaphore arms and so call on the driver to the starting signal.

Should the signals be "off", the driver only receives a "warning" signal which restores his miniature semaphores to danger and rings the bell On passing over the next ramp the appropriate arm goes to "clear" and the bell stops ringing.

Sykes-Tiddeman Train Stop—This employs a shoe and ramp similar to the Great Western Railway system and gives whistle and bell signals as in that system, except that the bell sounds while passing over the ramp only, as there is no local battery on the engine The shoe does not operate a switch, but removes a lock on a system of links which is con-

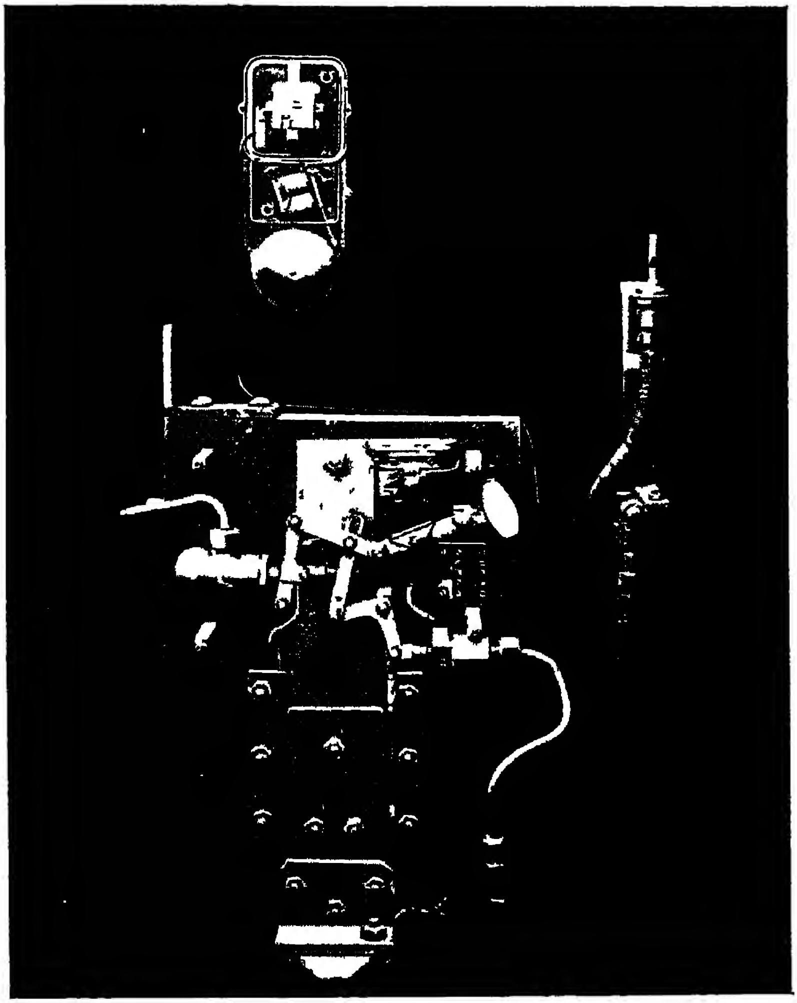


Fig 256—Sykes-Tiddeman Engine Apparatus

stantly under pressure from a valve in the train pipe (fig 256) When this lock is removed the valve causes the links to move and establishes a connection between the train pipe and the atmosphere through the whistle, thus gradually applying the brakes, unless the links are held in position against the pressure of the valve by an electromagnet, energized by the current picked up from the ramp The application of the brake is thus produced mechanically by the unlocking of the links when the shoe is

lifted The driver silences the whistle and stops the brake application by pressing a button which operates an air cylinder coupled to the links, and which resets them to the locked position The ramp is energized when the distant signal lever is pulled over, and in single-line working is controlled in the same way as in the Great Western system, the bell on the locomotive having a polarized mechanism, so that it does not ring when current is picked up from ramps applying to the opposite direction, these being negatively electrified by the block apparatus when a train is signalled The apparatus just described is for distant signals, for which the system was originally designed

To allow a locomotive to back past a ramp at a stop signal in shunting

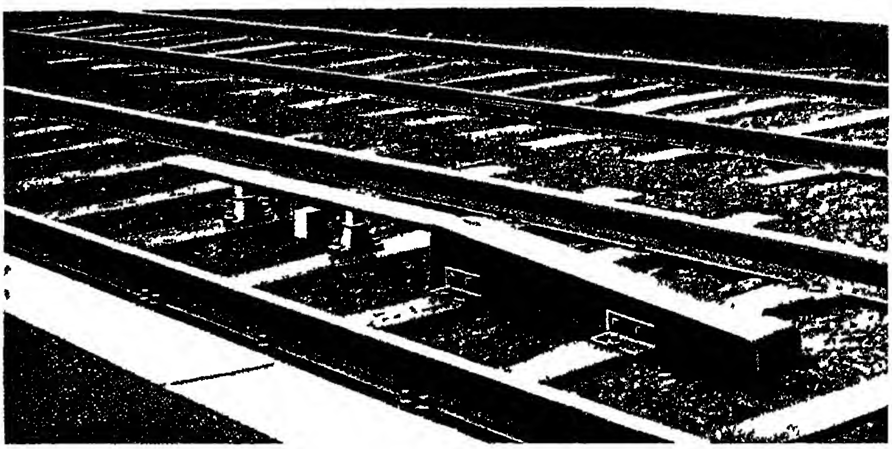


Fig 257 —J Colas' Anti-Frost Ramp, French Northern Railway

operations, &c , a special ramp is used divided electrically into two portions and connected to a stick relay in the signal box When the shoe first touches the end of the ramp in a setting back movement, it energizes the stick relay, and this connects a negative battery to the main portion of the ramp so that the brakes on the locomotive are held off, but no bell signal is given When the shoe passes clear of the ramp the relay in the cabin is released, and everything is restored to normal This system can be applied to locomotives fitted with steam brakes as well as with air or vacuum brakes or with any combination of these

Cab Signalling in France —For many years cab signals have been employed in France, notably on the Nord Railway, and, following upon serious accidents in recent years, their use has become or is becoming very general Many systems have been tried, but (with slight modifications on some railways) the Nord system is being everywhere used It is applied to warning signals (red discs, green discs, and green and white indicators), and consists of a contact ramp in the centre of the track which is connected to a battery when the signal is in the warning position Brushes on the locomotive make contact with the ramp, and the current de-energizes a

Hughes electromagnet and opens a steam whistle or siren, which has to be silenced by the driver operating a resetting handle In addition, on some lines, a mark is made on the band of the locomotive speed recorder, both when signals are on or off This apparatus is open to the serious objection that it relies upon picking up a current to give a warning signal In order to avoid poor contacts due to snow or ice, &c , ramps are now in use built on the Colas system (fig 257) The ramp is hollow and filled with petroleum Holes are provided in the top, fitted with wicks, and the oil gradually oozes out and over the surface of the ramp, preventing any freezing mixture from settling on it (see fig 258)

Automatic Train Control in America.—There are very many systems of train stops and train control in America, including ramp systems, inductive systems, speed control systems, &c , some of which are very complicated and elaborate The number of disasters due to drivers ignoring signals has been so great in recent years that legal measures have been taken, as has already been referred to, and most of the large railways compelled by the Inter-state Commerce Commission to install automatic train control apparatus on a passenger train division, all locomotives working on such division having to be fitted with the necessary appliances A few installations have been completed at the time of writing, and the results of this enforcement of the adoption of train-stop devices will be watched with much interest

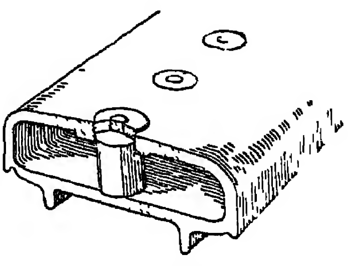


Fig 258

There is another phase of signalling in thick weather which must not be overlooked, viz the conveyance of information to the signalman as to the presence of a train in his section and whether the train is complete

Track circuits with an indicator in the box showing " track occupied " or " track clear " as the case may be, tell the signalman that a vehicle or vehicles are on the track-circuited length It is necessary, however, for a " groundman " to be posted immediately outside the signal box to tell the signalman that the tail lamps on each train are in position, and also in some cases what train it is that is passing Arm and light repeaters let the signalman know that the arms are in the correct position and that the lamp is alight behind the spectacle glass

Engine whistles also act as reminders to signalmen as to the presence of a waiting train

CHAPTER XIII

Telegraphs and Telephones in Railway Service

The telegraph, assisted later by the telephone, has been one of the chief means by which the successful operation of railways on a large scale has been made possible, not only from the safety point of view, but also from the commercial, as the immense number of business operations necessary for the efficient management of a railway, even a very small one, would be impossible without some rapid and reliable means of communication between the various administrative centres and between the officers and staff responsible for traffic working The telegraph was introduced in the early days of railways, the first installation having been erected by Cooke and Wheatstone on the Great Western Railway, between Paddington and Slough, in 1839 It became popular immediately owing to its use having led to the arrest of a murderer In twenty years' time a widespread network of telegraphs existed for public use, and a considerable number of the lines passed along railway routes, a condition of affairs which still obtains in many parts The railway companies were not slow to realize the importance of telegraphic communication for their own business, and installed a great number of circuits uniting the principal points and offices on their system as well as signal boxes, level crossings, &c

Lines —For some time open line wires were invariably employed, and the majority of telegraph circuits are still built in this way, but in later years cabled circuits began to be used, a practice which has been rendered absolutely necessary in some places owing to the adoption of electric overhead traction systems, especially in America and on the Continent Cables also offer the great advantage of being free from disturbance in severe weather Sleet- and snow-storms often seriously dislocate traffic by bringing down the wires, and considerable expense is incurred in restoring communication The detailed construction of telegraph lines is beyond the scope of the present work, and readers are advised to study the well-known Post Office manuals on this subject

Whether required for railway purposes or for the ordinary public services, the technical requirements are almost exactly similar and form the special province of the telegraph engineer On some railways, such as the Great Western and Southern Railways, the signal engineer or superintendent has charge of all telegraph and telephone work, while on other lines a telegraph superintendent deals with it, although sometimes the block signalling apparatus, signal repeaters, and similar appliances are considered as belonging to the signal engineer's jurisdiction

Both iron and copper line wires are employed, but the tendency is for copper to be used instead of iron, as it enables more rapid signalling

to be carried on, especially on long circuits, while the increasing use of the telephone, both on separate telephonic circuits and superimposed on other circuits, such as telegraph and block circuits, renders the use of the better conductor necessary Copper line wires are, of course, dearer in first cost, but a careful study of all figures entering into the cost of laying down and maintaining lines for a term of years appears to show conclusively that they are more economical in the long run In certain places where corrosion is particularly prevalent their use is absolutely essential The employment of anything but the best quality material, especially in the matter of poles and fittings, is not good practice, and any economy temporarily obtained in this way is certain to be counter-balanced later on The erection of the wires calls for care and skill, as a badly built line will suffer from severe stresses in bad weather if it has not been constructed to bear them properly The railway companies and the postal authorities have very strict specifications covering materials and constructional work, and too much care cannot be taken to see that they are adhered to

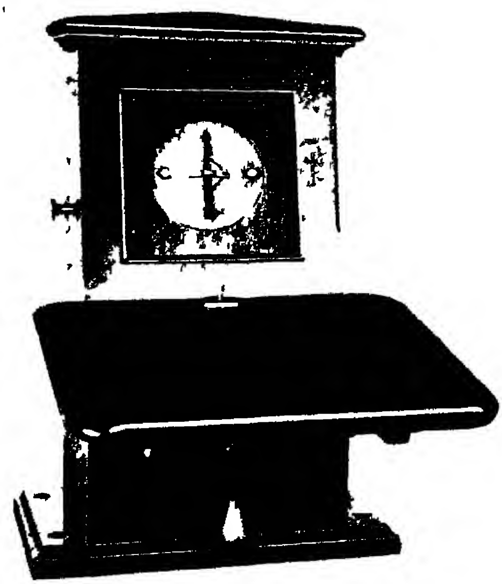


Fig 259 —Single-needle Instrument

Both on aerial and cable lines it is necessary to have proper means of isolating certain sections and of testing from point to point in order that a fault may be located and rectified within the shortest possible time A fault on a busy line will cause the greatest inconvenience, while a breakdown of a block-signalling circuit or of a wire carrying a control circuit for some track-circuiting installation or similar purpose may necessitate hand signalling or permissive working being temporarily instituted, with all its attendant delay and dislocation of traffic The heavier the traffic the more important these precautions become, as even a short delay may upset the train movements for a long time Next to the prevention of faults, which cannot of course be totally eliminated, their rapid removal is of primary importance in the successful working of a railway telegraph or telephone system

Instruments —The single-needle instrument, fig 259, has been largely used in Great Britain for railway work, as it is simple in construction and easy to use In Ireland, America, and in Continental countries,

however, the sounder or Morse writer has been employed The bell double-plate sounder has been largely used on some English lines

The arrangement of the instruments on each circuit depends on the nature and volume of business it is required to carry If there is a number of instruments some code call signalling is necessary to attract the attention of the operator required, the code being seen (or heard on acoustic type instruments) at all stations simultaneously Too many instruments must not be connected to one circuit, otherwise great inconvenience is caused by the line being engaged when others wish to use it The traffic requirements have to be studied with care and the circuits planned so as to admit of communication being carried on with the minimum of delay Switches can be placed at selected points to separate circuits and reconnect them for special purposes, such as at night or at times of special traffic, race days, &c On the trunk lines the refinements of modern telegraphy, such as duplex and quadruplex working, automatic, high-speed, and printing telegraphs, are now to be seen on circuits where the pressure of work is constant and heavy All such appliances, however, require skilled operation and maintenance far above that necessary for the older Morse or needle systems The single-needle instrument or sounder is not very suitable for signal box work as, in the nature of the case, signalmen are not expert operators, and the speed of signalling is therefore rather low Accidents have happened through messages taking a long time to transmit, and the telephone has now superseded the telegraph for what is called box to box work For local messages it is in every way more suitable and flexible For certain classes of messages, however, telegraphs are better than telephones and will continue to take a prominent place in railway operation

Organization of Railway Telegraphs.—Generally speaking the telegraph system of a railway would consist of a head-quarters centre, and certain sub-centres from which in turn would radiate local networks The grouping of the railways in England has, however, produced a condition of affairs somewhat similar to that obtaining in some Continental countries which have state railway systems, there being now, for one railway group, several administrative centres of almost equal importance from a telegraphic point of view This naturally gives rise to a large amount of through message work which must be taken care of by a sufficient number of direct circuits to avoid unnecessary re-transmission and overloading of local circuits In organizing a system of communication, regard must be had for a number of factors in deciding how to plan the circuit arrangements on the most economical and efficient basis The choice of apparatus also must depend on similar considerations Messages of local importance only should be kept clear of through circuits which are busily occupied, or much inconvenience is caused by work having to wait its turn The general arrangement of the system requires reconsideration from time to time, as business arrangements in localities vary and the railway work varies to meet

them Unnecessary telegraphing should be avoided There is a strong temptation to telegraph when a letter or train message will serve equally well, but every unnecessary telegram means a reduced opportunity for necessary ones to get attended to It is customary to employ certain conventional signs, known as prefixes, at the beginning of telegrams in order to indicate their nature and degree of urgency, as, for example, DNG—danger signal, GM—extremely important, SP—special service telegram, DB—general railway message, and so on Proper steps must be taken to see that such prefixes are not made wrong use of and priority on the circuit wrongly obtained The use of the telephone in recent years has resulted in much work being taken from the telegraph which at one time had to be done by it, but the general principles under which a telegraph service is carried on remain the same

Code Messages.—Some railway companies employ a code, resembling in principle those used by commercial houses for cablegrams, in which a single word, or a combination of letters or figures, is used to signify a complete sentence, or a large part of one For example, the word "GUM" may mean "In reply to your telegram" Such a code enables the length of telegrams to be much reduced and therefore saves time in transmission, which is important on busy circuits, but, of course, the message has to be decoded by the recipient If the code is not too large, however, and words easily kept in mind are used, this may often be done without referring to the code book Word codes are better than letter or numeral codes, as there is far less chance of a mistake being made in transmission Wherever possible it is probably better to give messages in full, but under certain circumstances a code becomes exceedingly useful For railway purposes it should certainly be kept within reasonable size

Time Signals.—An important function of the railway telegraph is to send the correct time every day at a given moment to all stations on the line, so that clocks may be regulated accordingly, as proper time-keeping is essential to safety and the regularity of train movements The time signal is sent out from a central office, which obtains a signal from Greenwich, or some other observatory, all stations preparing a few minutes before the appointed hour to receive the time signal On the German State Railways, at Berlin and elsewhere, important time signal installations have been laid down in conjunction with the electrically driven and regulated clocks in the various station offices, cabins, &c , throughout the division Many English railways have adopted electric clock installations for their offices at large stations and yards, but there is as yet no installation so comprehensive and complete as those to be found on the German lines

Tunnel Warnings.—In long tunnels it is very advisable to install some means whereby communication can be made at once with the signal boxes and stations at each end, in the event of an accident occurring or some defect in the tunnel or track being observed by the permanent way men In the Woodhead and other English tunnels this has been done,

as well as in the Simplon, Mont Cenis, and other tunnels abroad At regular intervals throughout the tunnel a telephone or alarm signal post should be established and the circuits led through so that the simple manipulation of a plunger or switch is enough to sound the alarm in the cabins concerned The closed-circuit principle of working should, of course, be invariably employed so that the apparatus is self-testing By using telephones in conjunction messages can be rapidly transmitted, and information immediately given On the London Underground Railway system, bare line wires are provided along the walls of the tube tunnels, and by means of a portable telephone set carried in the motorman's cab, which can be connected to the wires, communication can be made with the nearest station, signal cabin, or traction substation On underground electric lines it is necessary to have some means of getting the traction current switched off at once, and as it was found that delay arose at times in the transmission of telephone messages, a system has now been devised and is in use whereby the motorman has only to press the two wires together to cause the current to be cut off automatically This is a very valuable safeguard The consequences of a bad breakdown of insulation on the equipment of an electric train in a tunnel may be so very serious, in spite of all precautions in the way of the use of fire-proof materials, that some means of cutting the current off instantly is most desirable

Telephones —No instrument has assisted the signalman so much in handling the traffic expeditiously, or the operating officer in keeping in touch with its movements, as the telephone It is now in use in every signal cabin and at all other points of importance, such as stationmasters' offices, locomotive depots, goods yards, &c , entirely taking the place of the telegraph instrument for the general message work required at such places Recent years have seen remarkable steps forward in telephone engineering, and in some areas, such as the London area of the Southern Railway (S W Section) the old single-needle installations have entirely disappeared and been replaced by telephones As with telegraphs, the circuits have to be arranged to meet the class of traffic to be conducted over them For box to box work and communication between signal boxes and stationmasters' offices or similar points, omnibus circuits are used This consists of a number of telephones being connected in parallel on a line, and a system of code rings used to denote which person is being called Too many telephones should not be connected to one circuit, as the code then becomes very complicated, the line is overloaded, resulting in delay and annoyance, and the continual ringing of code calls is objectionable Fig 260 shows the connections used on one large railway In busy signal boxes, where there may be several telephones on different circuits, the code ringing is very annoying as it interferes with the signalmen attending to their block signalling duties, while a code call, which may nearly resemble some other one, can easily be overlooked or answered by mistake To avoid this, selective ringing telephones have

been introduced and are to be found on the Great Western Railway and to a large extent on the German railways, where several types are in use, some operated by batteries and some by magneto generators With them only the person intended receives a call and the other instruments remain silent, which is a very great improvement Selective telephones are, however, more complicated, and require more skilled maintenance than the ordinary omnibus type On British railways telephones are very often found superimposed on other circuits, while telegraph circuits are also superimposed on those used for telephones Practically all the telegraph circuits emanating from Paddington, Great Western Railway, are superimposed on trunk telephone circuits The same working has been widely used on other railways, and very considerable economies have been realized thereby

Telephone Exchanges—The extended use of the telephone in railway offices has rendered it necessary for railway companies to erect telephone exchanges for their own purposes, the requirements having now got far beyond the capacity of the intercommunication type of telephone which at one time was so much used for office work Such exchanges may be manually operated, but the tendency now is to install automatic exchanges, which give quicker and more reliable service and enable operators to be dispensed with or reduced to a minimum number There are several systems of automatic exchange, which have been developed to a surprising degree of perfection The internal service of a large administrative centre can be carried on entirely automatically, but an operator is necessary to attend to external

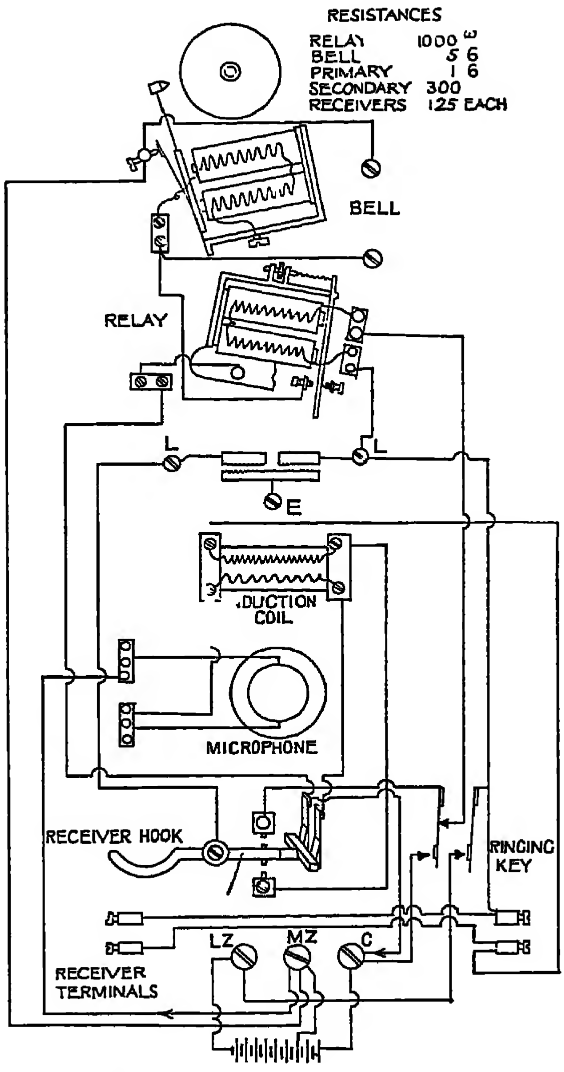


Fig 260—Connections of Signal-box Telephone

calls in both directions Where there are other automatic exchanges in the vicinity, however, the calls between them can be handled automatically, and, theoretically, there seems no limit to what can be done with automatic systems They are being continually extended and improved as demands arise Exchanges are also used, notably in the United States, in connection with telegraph circuits but are principally to be seen in connection with public services and only to a lesser extent for railway work

Emergency Telephones.—In Germany every train carries a portable emergency telephone which can, by special clips and leads, be connected to the wires alongside the railway, so enabling communication to be established at once with the nearest signal box or station The telephone circuits are indicated by metal tags affixed to the insulators on the poles In addition to this small telephone huts are fixed at intervals along the line between stations, which can be unlocked by a railway key and contain a telephone connected to the local circuit The telegraph poles have arrow indicators affixed to them showing in which direction the nearest telephone hut will be found This system, which is very thoroughly carried out in Germany, is not so necessary in Britain, where signal cabins and stations are not, as a rule, very far apart Nevertheless, such emergency telephones are to be found in some places, where the distances between stations is great or where danger is especially to be feared from landslides or heavy snowfalls

Control or Dispatching Systems—In the United States it early became the practice to regulate the traffic on the railways, which were for the most part single lines, by what is known as a train dispatcher, that is an officer stationed at some important point, generally the chief station of a division, who was in telegraphic, or later telephonic, communication with all other stations, and who was kept continually in touch with the train movements by reports sent over the wires to him At one time the safety of working very largely depended upon the dispatcher, as there was practically no signalling at all, and if he issued wrong instructions to trains or his instructions were wrongly transmitted, misunderstood, or neglected, as often happened, very serious consequences could ensue Normally, the time-table rules, if obeyed, provided full security, but it often became necessary to depart from the time-table for many reasons, and to regulate what should be done in such circumstances was the duty of the dispatcher As signalling was introduced the dispatching system was retained as a traffic regulating arrangement, but lost its character as a safeguard against accidents As long as it cannot lead to an accident, a dispatching system is a most valuable instrument in the smooth working of traffic, as much better co-ordination of effort can be obtained, especially in dealing with exceptional traffic The dispatching system is universal in the United States, but has only in comparatively recent years found a large application in Europe This is due to the different circumstances under which European railways developed and to the much wider

use of good signalling appliances on them than on American lines in earlier years Now, however, the value of the central traffic authority has been recognized, and there are many extensive dispatching installations at work In Great Britain, however, the term train control[1] is used Traffic control would be a more suitable name

Classes of Dispatching or Traffic Control —The general principle involved in the idea of traffic control may be applied in a number of different ways, and may be extended to cover every kind of traffic movement, or limited to certain kinds only, there being installations of every degree of completeness in Europe For example, the dispatcher may have complete authority over the traffic, as he does in America, or over

Fig 261 —Traffic Control Office

certain classes only One may have a goods traffic controller or a locomotive controller, and so on The tendency is no doubt towards a complete system, as any partial system is bound to have certain undesirable features in most cases

Arrangement of Traffic Control Installation.—This involves a central office with a ready and rapid means of communication with all stations, signal boxes, locomotive depots, and yards in the area concerned In the office there must also be an efficient system of recording train movements as they are reported, and in such a manner that the controller or dispatcher can tell at a glance the exact situation from one moment to another The Morse telegraph was, of course, the universal means of communication used at first in America, but this has given way to the telephone, which is in every way better, as it allows of the system being

[1] Not to be confused with automatic train control

Fig 262—Traffic Control Office Leeds

worked without having to employ skilled telegraphists Several systems of "selective" telephones have been used The general arrangement of them is usually as follows

From each control office pairs of wires pass along the railway, and each pair has connected to it a number of "way stations" With the Western Electric System the number which can be connected in parallel across one pair of wires is very large, but the ruling factor is not a technical one but a traffic matter If the telephones are frequently used, only a relatively small number of them should be connected to the same line, otherwise delays may take place owing to the line being engaged when another station wants to forward some information

In the control office the telephone lines—there may be 3, 4, 5, or more—are lead to controllers' desks, fig 261 In front of the operator on a back board are mounted small electric lamps coloured white and red The same telephone lines are connected to all the desks If a line is engaged by one desk a red light shows at the other desks In the control office illustrated, the recording of the train movements, &c, is dealt with by cards which are placed in appropriate compartments in the stands shown

Another type of control office employs a large map or diagram of the area over which it operates Fig 262 shows a control office of this kind, equipped with the Western Electric System of traffic control telephone apparatus

To enable a desired way station to be called without ringing a bell at the other stations on the same line, a selective system is adopted There are a number of these systems One depends on combinations of polarized and non-polarized relays, and another on step-by-step relays, which respond to impulses sent out by the controller Fig 263 shows the circuit diagram for the Western Electric System which employs step-by-step relays

The speaking and listening circuits can be either local battery speaking or the central battery system The latter system, while making a good line essential, saves a considerable number of primary cells at the way stations and so reduces maintenance

If a controller wishes to call a way station he turns his selector mounted in front of him to the station required and then sends out a selecting current, after which follows a ringing current from a vibrator, or motor ringer, or hand generator, which rings the bell at the way station after the selective relays have responded

With the lamp signalling system, if a way station wishes to call the controller he listens in on the line, and if it is not already engaged he presses either one or other of two buttons on the instrument, and causes a line relay to close at the control desks and a white light to be shown The controller then plugs or switches his head-set into the line calling, and conversation takes place

With the two-button system, it is possible to call one of the desks only, for instance, the controller who deals with relief of enginemen and guards In this way a further selectiveness is provided

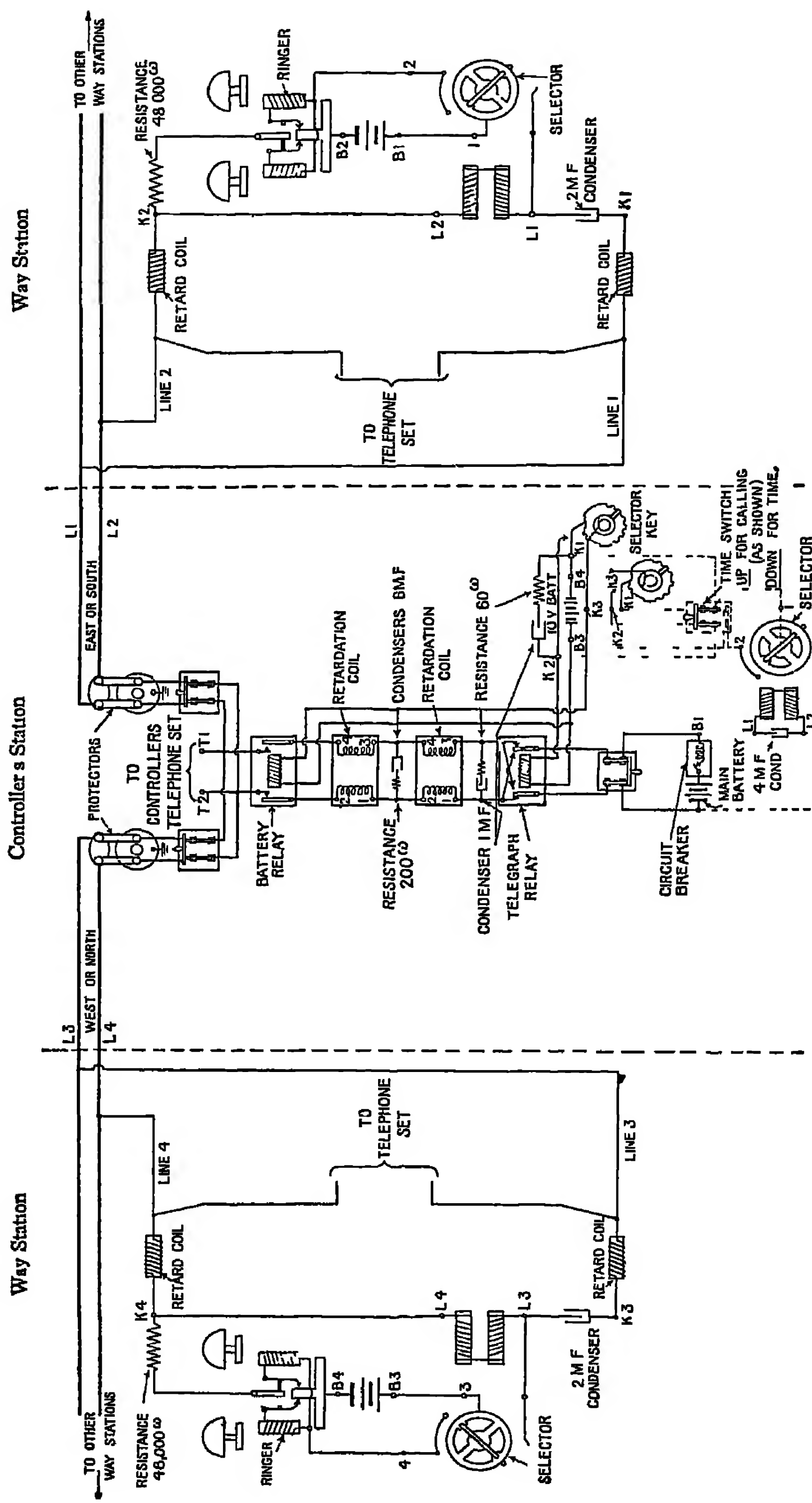


Fig 263 —Traffic Control Circuit Diagram

With the Western Electric System, after listening on the line to ascertain that it is disengaged, the button on the instrument is pressed, which drops an indicator on the controller's desk apparatus

The traffic control circuits are only for the purpose of exchanging information and instructions between the controller and the staff on the line The way stations cannot communicate with each other by them, but must use the ordinary railway telephone circuits for that purpose One or two installations have been made in which the ordinary circuits are used for the control work, but the arrangement is most unsatisfactory and causes much discontent among the signalmen, who find their local omnibus telephones constantly engaged by control conversations The nature of the traffic to be regulated also influences the circuit arrangements It has been found necessary in some cases, as on the Belgian State Railways,[1] to have separate circuits for up and down lines with separate controllers, seated, of course, at adjacent desks Theoretically, single-circuit working is better, but a very intense traffic makes it impossible to employ it without having a small control area if the work is to be kept within bounds A small control area is, however, unsatisfactory, and does not give a controller enough scope to exercise his powers to real advantage To secure the best arrangement of circuits and sections, it is necessary to arrive at a compromise between a number of results desired, aiming specially at getting the longest sections possible, making them coincide with the locomotive and traffic divisions and locating the controller at the same point as the division superintendent The dividing point between one controller's area and another's should not come at a busy station, if it can possibly be avoided The exact duties of the controller will vary with the completeness of the system of working adopted In some installations, for example, he has the power to veto the running of a special train, in others, a special train may be put in service by a station, even against his advice, although it must be sought before deciding the matter On the Continent, where the authority of the stationmasters in such matters has always been considerable, the dispatching system has been introduced without unduly interfering with them, as far as possible, but there is often a considerable difference between one railway and another in the precise duties and powers of the dispatcher Several control systems are in use in Great Britain, but here again there are many points of difference between the various installations

Practical Results of Traffic Control.—The experience of all the railway administrations who have installed traffic control systems has been very favourable, and has proved that great economies may be effected by their use Better regulation of traffic means better and therefore more economical use of rolling stock and men, which reflects itself in a saving of money The unnecessary running of light engines or empty vehicles,

[1] Readers should consult the issues for November, 1922, and May, 1924, of the *Bulletin of the International Railway Congress Association* for an excellent account, both technical and practical, of telephone traffic control

the unnecessary duplication of trains and the overtime of train crews can be, if not entirely avoided, reduced to a minimum, while by arranging that both locomotives and rolling stock shall be where they are wanted at the right time, better paying loads can be run The large Continental railway systems which have adopted traffic control or dispatching on an extended scale, such as the Belgian and Czechoslovakian State Railways, the Paris, Lyons, and Mediterranean and Orleans Railways, have been able to report very large savings, justifying the adoption of the system, in a very short time On the Belgian lines the locomotive depots were able to show a 40 per cent reduction in fuel in the first year of working The better time-keeping which results improves the public confidence in the railway, and brings increased patronage Among the many means which the advance of technical knowledge has put at railway companies' disposal for the reduction of operating costs and the increase of revenue-producing traffic, dispatching or traffic control by telephone is one of the most striking and valuable

Conclusion—Telegraphy and telephony are to-day such highly developed arts that it has only been possible to touch briefly on them and their application to railway work in the preceding remarks Detailed information on the subject may be found in several of the works given in the bibliography

---

CHAPTER XIV

Electrical Power and Line Construction

I—ELECTRICAL POWER

The earliest source of electricity for railway signalling was derived from primary cells, particularly those of the Daniel and Leclanché type

Since those days the demand for electricity for working the very many different circuits used in signalling and communications has enormously increased, and the cost to a large railway company of the power derived from the many various sources runs into many thousands of pounds a year

Circuits can be grouped in two classes, viz those requiring generally a continuous, steady, or fluctuating current, and those only requiring current intermittently "Intermittent" can be defined as a period of discharge of less a minute These circuits can be again grouped in accordance with the amount of current required Thus an arm and light repeater only requires 4 to 12 m a, according to type, to move the indicator, whereas a telephone exchange may require up to or more than 10 amp

In the former class can be included track circuits of the continuous

indication type, track indicators, electric detection, alarm systems, C B telephone systems, telephone vibrator ringers, arm and light repeaters, double-current duplex and quadruplex telegraph circuits In the intermittent class are electric bells, electric locks, transient track circuits, block instruments, telegraph (single-current morse sounder and single needle), electric signal machines, low-voltage point machines, certain telephone ringing circuits

The continuous current groups are as follows

A C Up to 20 m a , generally constant

Arm, lamp, or slot indicators, Spagnoletti movement	10 m a
Arm, lamp, or slot indicator, Tyer's	4 m a
Track indicator, Spagnoletti movement	16 m a
Detection relays	12 m a

B C From 20 m a to 100 m a , generally constant

Track relay, 4^w G E C type	90 m a
Track relay, 9^w G E C type	70 m a
Track relay, 250^w G E C type	14 m a

C C From 100 m a to 1 amp , generally constant

Track circuits, 100 up to 250 m a
Switchboard lamp on C B board, 110 m a

D C More than 1 amp

A telephone exchange or controllers' switchboard with lamp signalling

The circuits requiring a current intermittently also come into these four classes, thus

A I Up to 20 m a , intermittent

Block instruments, both key and keyless, 10 to 16 m a up to 30 minutes continuously

B I From 20 m a to 100 m a , intermittent

Interlinking relay, 50 m a

C I From 100 m a to 1 amp , intermittent

Electric locks, 4 to 5 amp
Block bell, 4 to 5 amp

D I More than 1 amp , intermittent

Battery signal machine, 3 to 1 amp and 50 m a hold off
Low-voltage point machine, 3 to 5 amp
Some types of electric bells, 1 amp

The choice of the source of electricity to be provided to work these circuits is governed by many factors, such as distance from lineman's hut, technical experience of linemen, cost of maintenance of the batteries, &c , provided, amount of apparatus to be worked

Generally for classes A C , B C , A I , and B I , Lechanché cells of the sac or porous pot type or large dry cells are adopted

For classes C I and C C, while large dry cells will work, they are quickly exhausted, and therefore costly to maintain

The primary cell of the B S C O Edison-Lalande or Gordon type is favoured by some, while the portable accumulator is used extensively by one large railway

Portable accumulators will give good service, if (1) a first-class make of cell is purchased to a carefully prepared specification, (2) specially designed charging stations are installed at suitable centres, (3) the organization of the changing and distribution is thoroughly well done

With regard to the type of cell used, it is of the greatest importance, owing to the existing dimensions of battery boxes and carrying boxes, that the overall dimensions of each type of cell should not be exceeded, and secondly, that the number of types of cell should be kept as low as possible A 2-volt cell 120 ampere-hour and a 4-volt cell 40 ampere-hour capacity will be found suitable for all requirements Celluloid cases are favoured owing to lightness, and the ease with which the acid level and condition of the plates can be ascertained

Charging stations should be situated at centres where there is a good train service throughout the district to be served To save labour they should be as near to the station platforms as possible At least two men are required to work a charging station, one charging and dealing with the cells and the other assisting generally, addressing, booking, and dispatching the boxes of accumulators

A very good organization system for portable accumulators is to have every circuit on which an accumulator is used allotted a code letter A complete list of codes is held by the charging station, together with the destination station and changing date The District Inspector has a similar list and the Head Office another A lead tab, bearing the code, is attached to a terminal of the charged cell at the charging station, and the lineman, on receipt of the cell, changes it for the discharged cell to which he in turn attaches the lead tab The accumulator charger then knows he has received a discharged cell back from the circuit Suitable dispatching and received forms must be used and a strict check kept on the issue and return of accumulators

A rigid time-table is of course prepared and adhered to If it has to be departed from the lineman must be advised, otherwise he will waste time waiting for or searching for the missing cells

With a plant handling 1600 recharges per month it should not cost more than 8*d* per recharge, including distribution to the lineman

For class D C it is best to take a supply of power from a local authority if one is available, and if not, to put in a small power plant

A motor generator or a mercury-vapour rectifier, or one of the thermionic valve type, is necessary where alternating current alone is available A mechanical rectifier can be used when the current required is not more than 4 amp and the noise is not objected to Where direct current is available, it can be reduced to the required pressure by a motor generator

or through a resistance This latter means of reduction should only be used when small amounts of current are required, and there are reasons why humming should be absent

A method of charging accumulators by taking one cell or two cells and charging them without disconnecting them from the main battery is being worked out, and should result in the saving of the duplicate battery

At big railway centres where there are two or three or more large signal boxes with electric detection and track circuits, besides a telephone exchange and telegraph office, and perhaps a control office, it is economical in material and labour to install a central battery system for power supply

The voltage to the central battery should be chosen to suit the majority of circuits to be fed from it It is not necessary to install a 60-volt battery to work one 60-volt circuit taking a small current In this case, should 20 volts be the average voltage required, the additional 40 volts could be provided by a battery of dry cells in series with the accumulator battery This is usually done with a long-distance telegraph circuit

Telegraph and single-needle circuits, vibratory generators, and electric detection circuits should not be fed from a battery working a C B telephone exchange A C B telephone exchange requires 24 volts, with the positive terminal earthed, and no other circuit should be worked from the same battery, otherwise noises may be heard on the telephone circuits

It is desirable that detection and vibrator circuits, being of the constant-current low-voltage type, should have a low-voltage high-capacity battery

Telegraph, single-needle, and block telegraph circuits need at most a main battery having a capacity of 30 amp -hr , but the voltage may be relatively high These batteries require their centre earthed

In another application of this system, small-capacity batteries of accumulators—usually 8 to 10 amp -hr cells are employed—are placed in each signal box and are fed by a steady trickle charge of 30 m a from a central battery through a pair of wires The current is reduced by bobbin resistances

Bus-bars are mounted in cabinets in the signal box by the instrument shelf, and tappings to the various instruments, such as block bells, block disc indicators, locks, indicators of various kinds, are taken from them, the current being reduced by bobbin resistances to the required amount

It will be found on investigation that there is a real saving in primary battery material, battery accommodation, and labour in constantly attending to the primary cells, by putting in the central battery system at a large railway centre

Another application of this system is to feed signal boxes individually from a battery of portable accumulators, which are changed at fixed intervals, say every month for 100 amp -hr cells It is found that a busy main line signal-box with two up and two down roads consumes 1 amp -hr at 24 volts every 24 hr

The apparatus is connected to bus-bars behind the instrument shelf,

suitable bobbin resistances being inserted in each circuit to reduce the current to the required amount

Hand Generator System of Power Supply —A recent development in the methods of obtaining power for the operation of points and signals is the introduction of the hand generator On the Continent the hand generator is not unknown, but its use in Great Britain as a substitute for batteries or power plant is new

The system, which is covered by the Nicholson-Roberts patents, consists of a hand generator, fig 264, and the necessary auxiliary apparatus

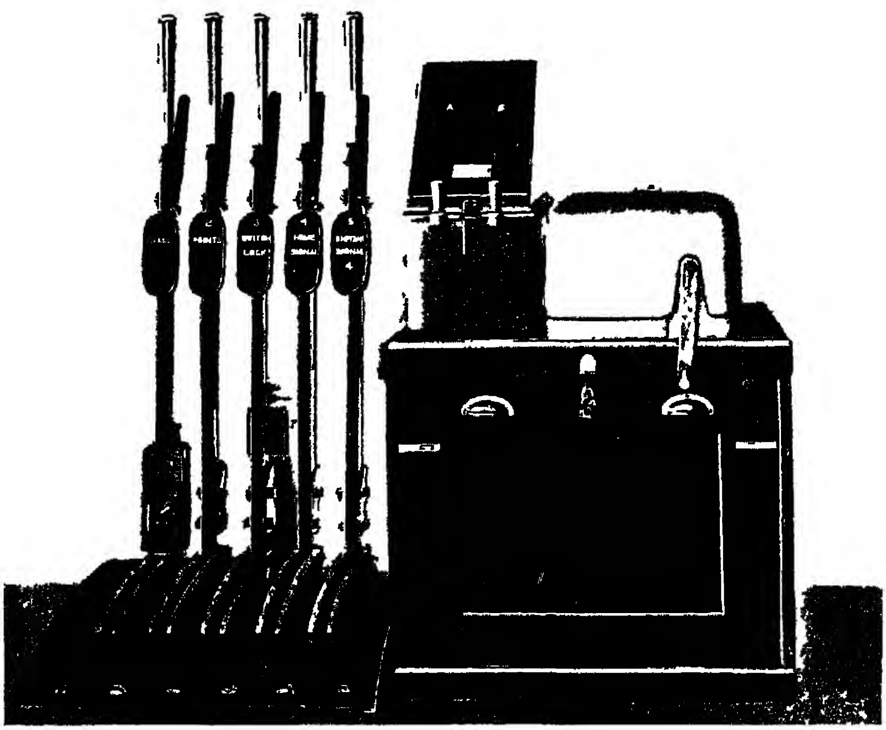


Fig 264 —Hand Generator Installation (Great Southern Railway, Ireland)

The generator is of the totally enclosed type, of robust construction, and 60–70 revolutions a minute of the handle gives direct current at 100–110 volts and up to a maximum of 1 2 amp Carbon brushes are provided

It is found in practice that to completely throw a cross-over road requires 8 sec The usual low-voltage point machine, drawing power from a battery, takes up to 20 sec A signal is cleared in a few seconds by the hand generator

The absence of a continuous supply of power on the power wires makes it necessary to provide a means of holding off the signal, and a bridging contact relay is connected into the circuit in such a way that when

the current from the hand generator ceases, the relay armature drops away, making bottom contact with a 10-volt battery, which supplies the few milliamperes required for the hold-off coils There is a moment of course when both the generator volts and battery volts are on the line at the same time, this being essential to maintain the hold-off coil energized

The hand generator system when used with point machines must be provided with a polarized control relay The function of this relay is to prevent any current reaching the hand generator

The hand generator system can be applied to existing mechanical frames by adding electric lever locks and circuit breakers The Westinghouse Brake and Saxby Signal Co , however, can supply with this system specially designed slide lever frames for small installations

Fig 264 shows a hand generator installation in Ireland at Charleville Station signal box on the Great Southern Railway This generator moves junction points 1850 yd distant from the signal box It also operates the signals at the same junction The point and signal machines used are of the usual 24-volt type, special 100–110 motors and gearing being fitted for use with this source of power

II —WIRES, CABLES, AND WIRING

Generally the conductors joining the various pieces of apparatus together do not give much trouble The worst places are where wires have to go under a railway or when open wires are employed in an atmosphere laden with fumes from chemical or other works

The important thing to bear in mind when designing the wiring or cabling for a signalling circuit is to prevent any stray or leak current operating a piece of signalling apparatus when it should not do so

While by using polarized apparatus the chance can be reduced, every effort should be made to prevent any possible contact between wires

Open Work —The classes of conductor used in open work are iron, copper, and silicium bronze The wires are supported on creosoted poles fitted with four- or eight-way arms, and nowadays the standard post office form of construction is adopted to some extent

Ferro-concrete poles with special fittings are on trial by at least one large railway company

A good arrangement for wires on poles is for the long-distance telegraph circuits to be on the top arms, a middle group consisting of telephone trunks, and a lower set of arms carrying block, repeater, track circuit, and local telephone circuits

Signalling wires should preferably be covered with an insulating material Some engineers favour V I R wire and others "indestructible" covering

Revolving telephone pairs is not entirely popular owing to the difficulty experienced by the maintenance staff in ascertaining whether wires

are in contact Also should a revolved pair or pairs break, it is not easy to pick up the right wires Straight telephone pairs are transposed by crosses at carefully selected points

Cables and Covered Work—Gutta-percha covered wires, both single strand and made up into pairs or quads, have been popular from the earliest days Modern electrical circuits, such as central battery exchange telephone lines, require a high standard of insulation, and gutta-percha covered wires do not prove entirely satisfactory Vulcanized india-rubber (V I R) insulated wire for indoor work is now extensively used For outdoor work where cabling is necessary, dry-core air-space paper insulated cables, lead-covered or armoured, are used For important signalling circuits where the question of a contact or earth is a serious one, impregnated paper lead-covered cables are adopted

If it is necessary or likely that extra wires will be required along the same route as the cable, then it is best to run it in trunking on stumps, with a capping which can be removed

For cables passing through tunnels, particularly dirty and wet ones, or where there is inadequate clearance, a heavily armoured cable of the submarine type is best No test points should be provided inside the tunnel itself, and as few joints as possible, but at each end, in suitable huts or cupboards, the cable should be terminated on test-strips, with lightning protectors connected to each conductor at both ends

Where it is necessary to take wires across a line of rails, if they cannot go overhead, then a special form of construction known as "surface work" should be adopted This method of carrying lead-covered cables possesses the merit of being free from vibration, and if the cable is laid in pitch it is also waterproof

Aerial cables are sometimes necessary when neither underground routes or open wires are feasible

The cables used for this purpose should be V I R or some similar material A special lead-covered paper cable is available, but the rigidity of the suspension is of the greatest importance If there is movement due to wind, then the lead sheathing will quickly crack

A form of aerial cable construction adopted in the United States for the transcontinental cables and other trunk lines is to use a "Bonita" ring clipped on to the suspender wire This does away with the swaying prevalent with the raw-hide suspender

The suspender wire is carried in clamps attached to each pole, and standing out from it Marline ties are made round the cable and strand on each side of each pole clamp, to lift the cable out of the adjacent Bonita rings to prevent ring cuts A very rigid form of cable suspension results, and trouble due to swaying or bending of the lead sheath does not occur The lead sheath should be earthed at regular intervals

For maintenance purposes, providing wires or cables are not liable to damage due to vehicles, it is best to have them above the surface and not underground In the event of a fault it is easy to trace it It is easier

to unscrew the capping of cable trunking than to pull a wire out of an underground route

Too much importance cannot be attached to soldered joints and clean and tight connections

For guarding against damage due to contact with power wires, the precautions adopted by the General Post Office Engineering Department are recommended

CHAPTER XV

Miscellaneous Apparatus

Signal Repeaters — Signal arms which cannot be seen by the signalman either by reason of their distance from the signal box, obstructions such as an over-bridge, or curve in the line, or being too close and above the convenient line of sight, are repeated in the signal box

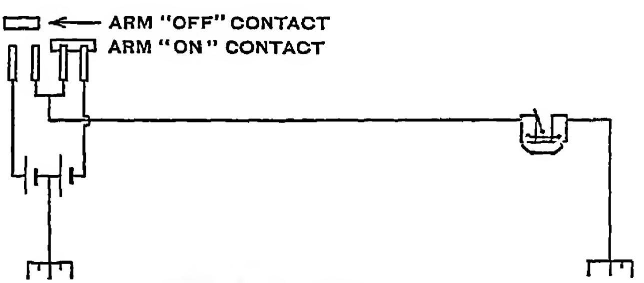


Fig 265 —Arm Repeater Circuit

The electrical circuit (fig 265) comprises an indicator in the signal box, a single line wire, a small battery of primary cells with centre earthed, and an arm contact

The indicator used usually gives three indications, viz arm "on", "wrong", arm "off"

The arm contacts only make within certain prescribed limits, which vary with different railways Thus the "on" contact will make only when the arm is within 5° above or below the horizontal, and the "off" when the arm is at an angle of 45° to 80° with the horizontal

Should the arm remain outside these limits, no contact is made, and the indicator flag shows "wrong" by gravity The arm of the signal operates a commutator, which may be of a spring contact type (fig 266), or of the mercurial type having a flexible connection to it (fig 267) Sometimes repeater contacts are worked off the signal-arm down rod, but this is not so satisfactory as working them by a direct arm contact It is very useful where signals are slotted to repeat the slot as well as the arm, as a signalman is sometimes in doubt as to whether it is his own control or the other signalman's which is out of order

Repeaters or Indicators —The actual form taken by the instrument installed in the signal box varies, and figs 268 and 269 show a type supplied by the British Power Railway Signal Company Another type has

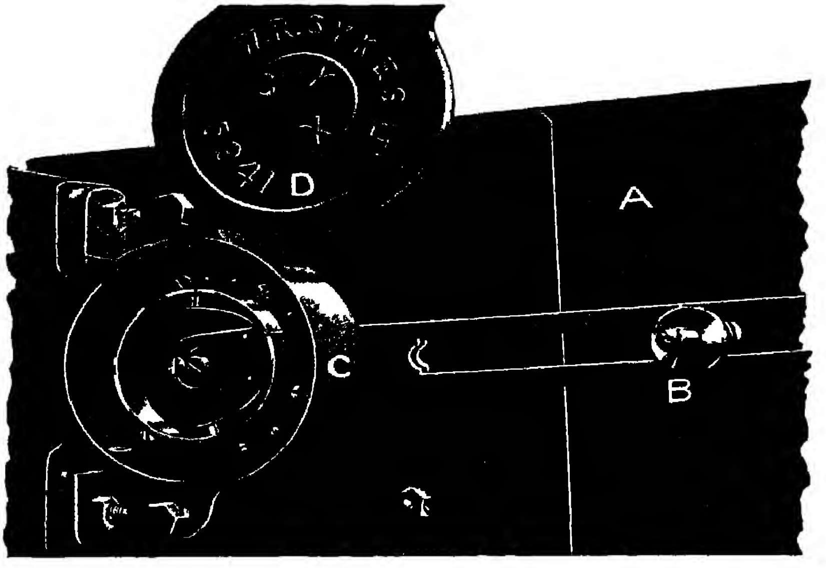


Fig 266 —Signal Arm with Spring Contact

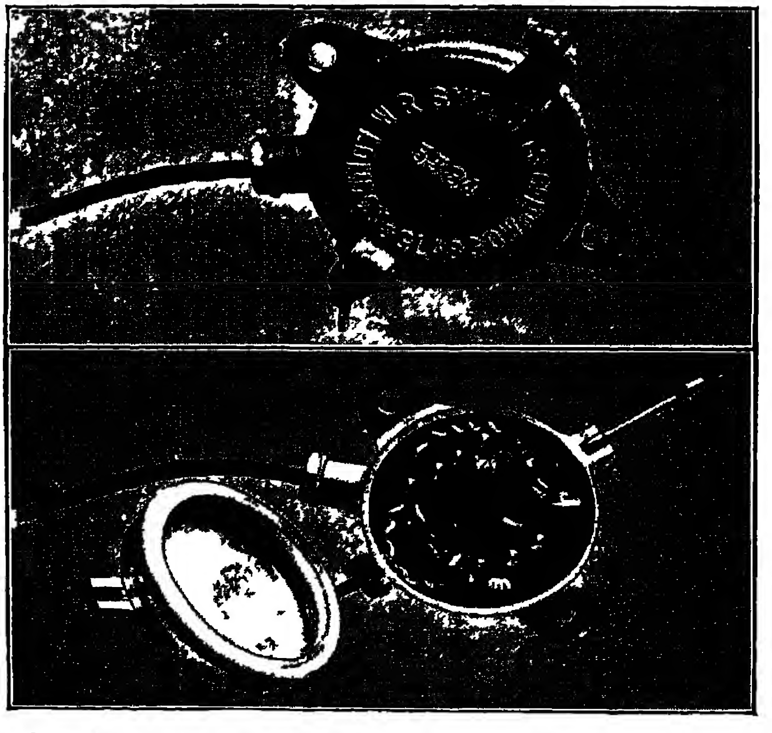


Fig 267 —Commutator of the Mercurial Type with Flexible Connection

a dial with an opening behind which a flag moves The flag is divided into three sections, coloured appropriately, and bearing the required wording

The Spagnoletti jewelled movement is generally adopted in these instruments, which require about 10 m a to operate them

Fig 268 —Home Arm

Fig 269 —Distant Arm

Three-position Signal Arm Repeaters

Battery switches are provided for use when signal boxes are switched out

Lamp Expanders.—For the same reasons that necessitate arms being repeated, the state of signal lamps has to be indicated in the signal box

Whereas with arms each arm has to be in most cases repeated individually, with lamps it is usual to connect a group of lamps to one repeater wire For instance all the lamps on a gantry could be repeated by one instrument In the event of one lamp being extinguished, the indicator would show "lamp out", and it would be an easy matter for the lampman to detect it The device used for detecting the presence of the flame of the lamp works on the principle of the expansion of metals when heated and contraction thereof when cooled

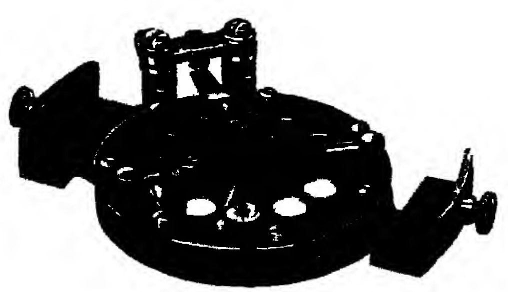


Fig 270 —Circular Thermostatic Expander

Fig 270 shows Tyer's new form of circular thermostatic expander for operating the electrical indicators in the signal box The expander consists of a circular skeleton plate, slightly convex, the expansion of

which causes electrical contacts to be made, and completes the circuit to the indicator, causing it to show "lamp in"

Should the flame be extinguished the expansion plate contracts, causing the contact or contacts to open, disconnecting the circuit to the indicator, so causing the indicator flag to be returned by gravity to the position showing "lamp out", and at the same time closing an electric alarm-bell circuit The design of this expander is such that it can be adapted to almost any type of lamp

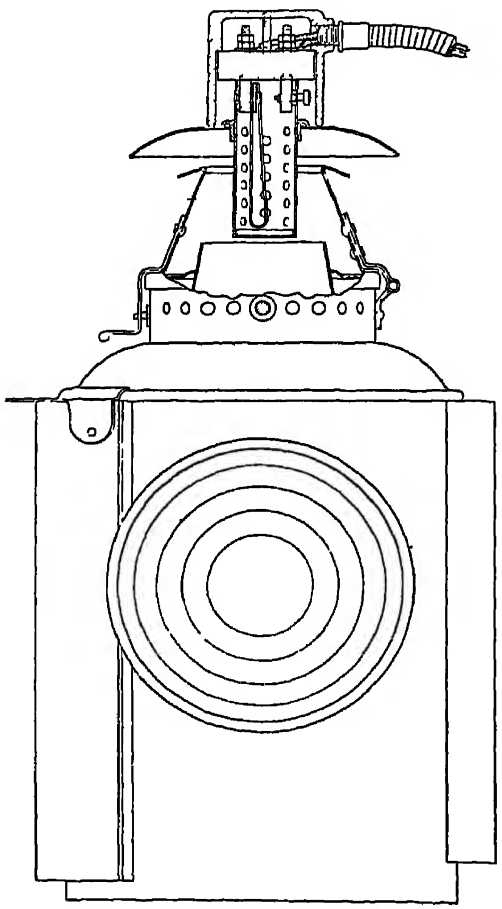


Fig 271 —Pyroscope fitted to Adlake Lamp

Fig 271 shows the British Power Railway Signal Company's expander or pyroscope fitted in the head of an Adlake lamp The pyroscope consists of a heat chamber containing an expanding metal member which, when acted upon by the hot gases ascending from the lamp flame, causes a contact to close The operating time from first lighting of lamp is 30 to 45 sec These expanders will operate should the flame diminish in size, causing a faint light to be given

Arm and Light Repeaters.—There are many situations where a signal consists of one arm and one lamp, both of which have to be repeated

It is possible to do this and employ only one line wire between the signal and signal box Fig 272 shows the simplified circuit diagram for the British Power Railway Signal Company's combined signal arm and light repeater

It will be noticed that to obtain the arm indications the current is reversed in polarity, but to obtain the light indicator the line current has to be reduced in strength This is accomplished by the opening of the pyroscope contacts cutting in a resistance without opening the line circuit

A group of lamps can be repeated in this way if desired

Sykes' Arm and Light Repeater (fig 273)—This only requires one line wire, but the strength of the current is varied by altering the arrangement of the battery instead of using a resistance A telephone exchange relay at the signal post changes the battery connections when the expander

operates The signal arm contact is in this case a commutator which reverses the whole battery

Tyer's Repeater —Messrs Tyer & Co manufacture an arm and light

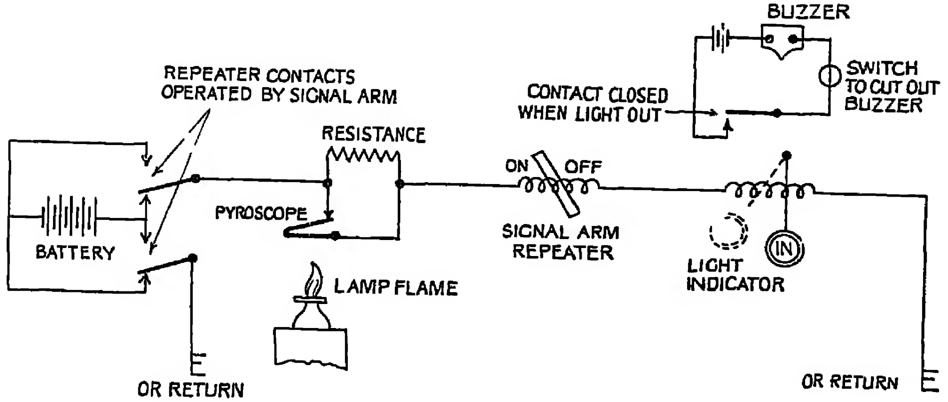


Fig 272 —Combined Signal Arm and Light Repeater Simplified Wiring Diagram

repeater in which a small electric bulb is placed behind a miniature spectacle and reproduces the actual signal lights

Detectors —Detectors are used to prove that points are in their correct position before the signal controlling a movement over them is allowed to show the "proceed" indication Should the points be in an incorrect position the "proceed" signal is prevented Mechanical and electrical methods are used, each possessing features and advantages superior to the other

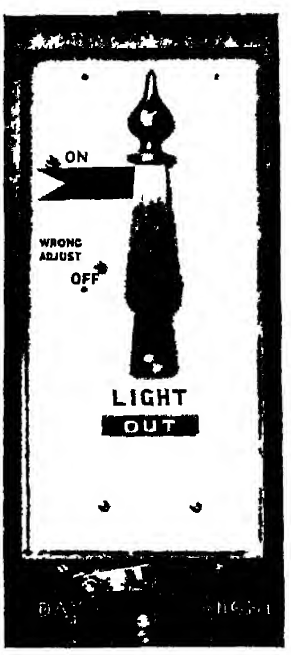


Fig 273 —Sykes' Arm and Light Repeater

Mechanical detectors usually take the form of crossed notched slides One set of slides is attached to the points, one slide to each tongue Lying across them, and suitably shaped, is a slide bar connected into the run of signal wire to the controlling signal

Unless the points are in the correct position, notches or "ports" in the slides do not register, and so the cross slide bar is unable to pass through the opening when the signal wire is pulled In this way the operation of the signal arm is prevented

An important advantage of this type of detector is that it acts as a mechanical lock for the point tongues, securing them against displacement while vehicles are passing over them

In large yards the detection of many pairs of points mechanically becomes a matter of considerable difficulty and expense both in installation and maintenance

In some cases a signal wire has to be run out to a pair of points some distance away, and then back to another pair and thence to the signal, involving a long length of signal wire and a stiff pull for the signalman

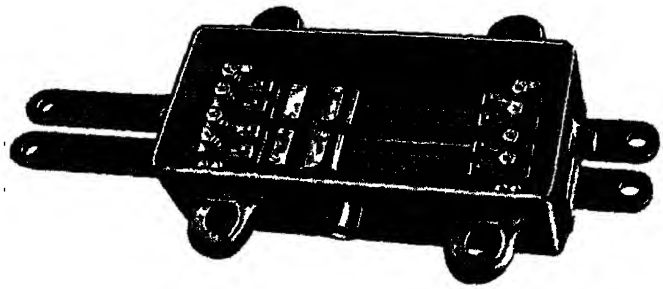


Fig 274 —Electrical Point Detector Contact Box

Compensation for expansion and contraction of the wire is difficult and crude, and not always satisfactory

By adopting electrical methods of detection shorter wire runs are possible An electrical contact box takes the place of the mechanical detector, and

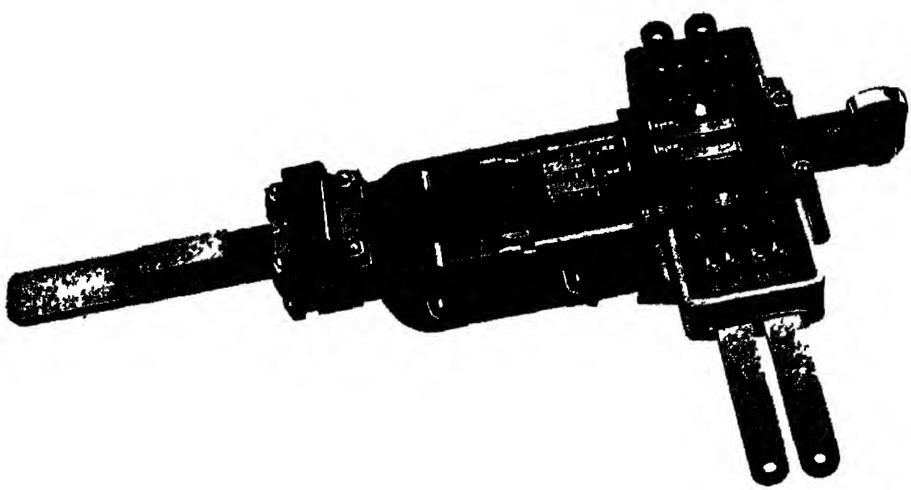


Fig 275 —Combined Facing-point Lock, Switch, and Plunger Detector

electric locks in the signal box on the signal levers hold them should the contacts fail to " make "

Up-to-date electrical detection employs polarized relays and currents of opposite polarity for the normal and reverse positions

Interlocked neutral relays are also used The best practice is to feed the power out to the detector boxes by separate mains, and for the relay wires to be run back to the signal box on a separate route The cabling

should be designed to prevent a release being obtained due to a contact or other fault

Fig 274 shows an electrical point detector contact box for trailing points by the British Power Railway Signal Company

Fig 275 shows a point detector contact box for facing points, also by

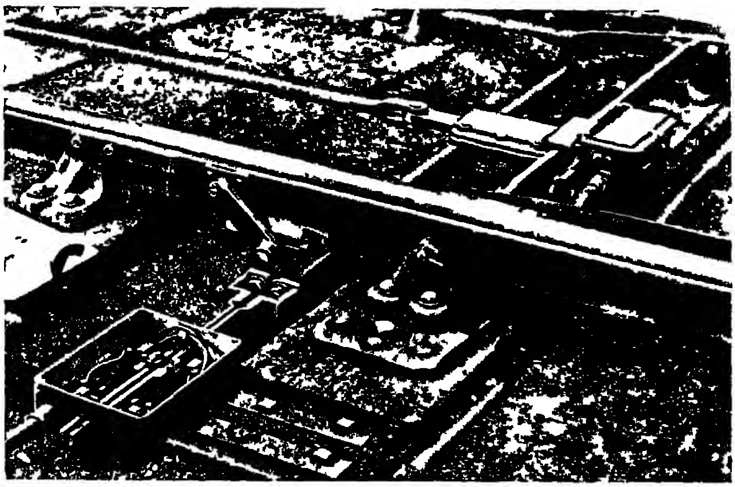


Fig 276 —Sykes' Point and Bolt Detector

the same firm It will be noticed that a separate slide and contact is provided for the facing-point bolt

Messrs Sykes were the first to employ electric detectors on a large scale in Great Britain and fig 276 illustrates their point and bolt detector. They also designed a special relay operating on the "Z" armature principle for electric detection at mechanical signal installations where, the circuits being complicated, the use of relays in the cabin was necessary This relay, widely used on the Southern Railway at Waterloo Station and elsewhere, is illustrated in fig 277 Both single and double (interlocked) patterns are made

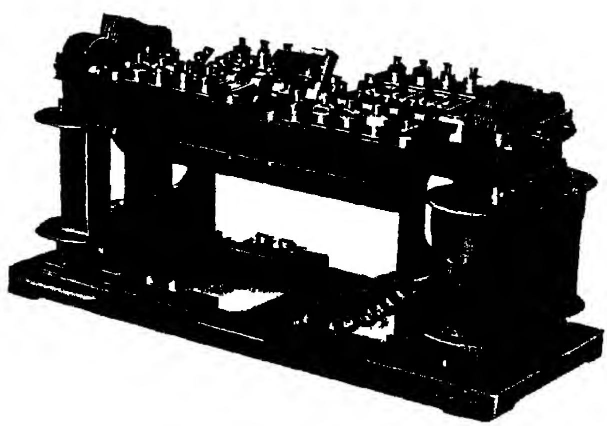


Fig 277 —Sykes' Point Detector Relay

On the Belgian State Railways every pair of points which can be run over by a passenger train in the facing direction is equipped with electric detectors, even at the smallest stations Fig 278 shows a detector for facing

points made by the Electric Construction Company of Charleroi, and extensively used in Belgium

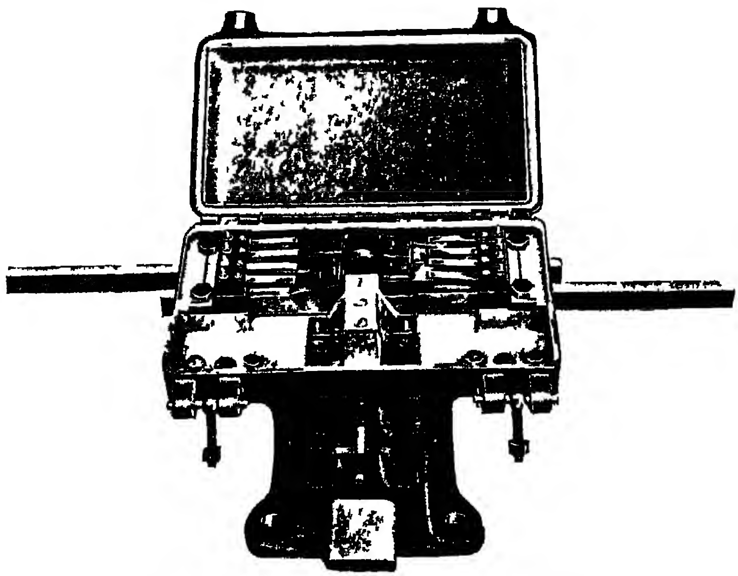


Fig 278—Belgian Combined Bolt and Point Detector

With electric apparatus a much more accurate detection can be obtained than with mechanical appliances, because with the latter much difficulty is experienced in adjusting wires, &c, and changes of temperature are a constant source of trouble[1] while the working of the signals is made heavier There is a constant temptation to the signal lineman to ease the detection by widening the notches in the detector slides in order to get over these troubles

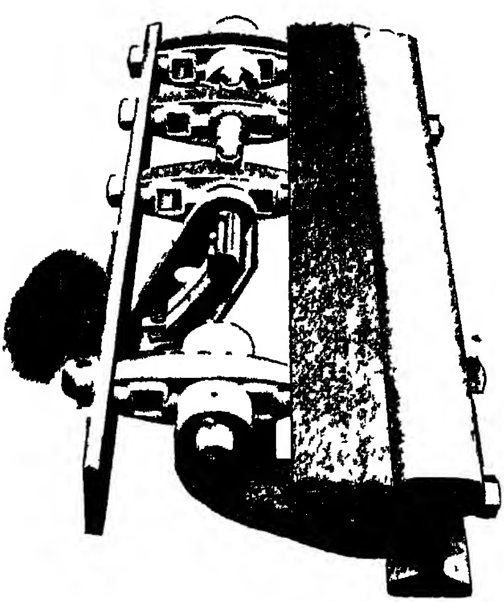


Fig 279—Electric Fouling Bar

Electric detection removes all additional load from the signals and can be made so accurate that the insertion of a coin in the points is enough to prevent a signal being pulled off

Electric Fouling Bar.—This is illustrated in fig 279, and consists of an angle-iron alongside the rail, coupled to a balance bar

[1] Except with the double-wire system of working, where the difficulties are very much less.

and arranged to stand normally flush with rail level and be depressed by the wheels of a vehicle, the length being sufficient to prevent the bar rising between them, as with mechanical locking bars The bar operates an electric contact maker or breaker, controlling a lock on a lever, an indicator, &c , as the case may be Where speeds are slow a short ramp at the end of the bar, about two feet long, is sufficient with an inclination

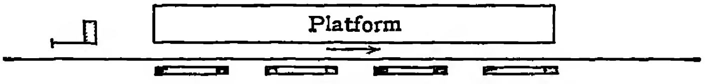


Fig 280 —Fouling Bars in Platform Road

of about an inch and a half, but with high speeds ramps 5 ft long or more are necessary, otherwise the shock is severe when a train passes over and soon destroys the bar Springs are sometimes used to take up the shocks Electric fouling bars may be applied to a variety of purposes They were much used at one time to protect platform roads in stations, several bars being placed at intervals (fig 280) so that a train would be sure to depress one of them and lock the relative signal Isolated vehicles cannot

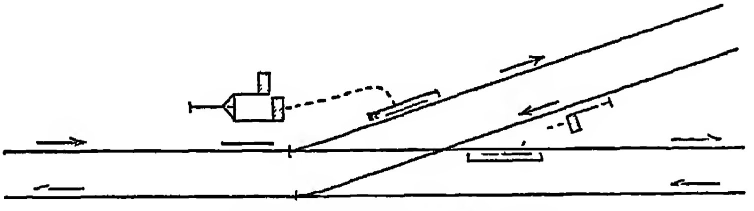


Fig 281 —Fouling Bars at a Junction

be protected in these circumstances unless the bars are placed very close together, which has been done at a few places, but is very costly It is usual, therefore, when the bars are not close enough to protect an isolated vehicle, to provide signboards indicating the location of the bars to trainmen so that they can be sure that a vehicle is protected when left standing on the line Track-circuiting has superseded fouling bars for protection of this kind, but, as previously explained, it is a valuable additional safeguard to

Fig 282 —Fouling Bar at Overlap

employ bars in conjunction with it at certain places Fig 281 shows an application of fouling bars at a junction to protect the tail of a train against a fouling movement Fig 282 shows a bar placed ahead of a signal to act as an overlap The bar locks signal *a* and thus this cannot be cleared for a train to proceed up to signal *b* unless the preceding train is clear of the bar This is provided at places where cabins are very close together, and a long goods train standing at the home signal of one box may reach back almost to the advance signal of the box in the rear Fig 283

shows a bar unlocking a call-on signal It is the rule on some lines not to clear a call-on signal until the train has come to a stand In the scheme

Fig 283—Fouling Bar controlling Call-on Signal

shown the signal is locked until the bar is depressed, which practically compels obedience to the rule Electric fouling bars can also be used as

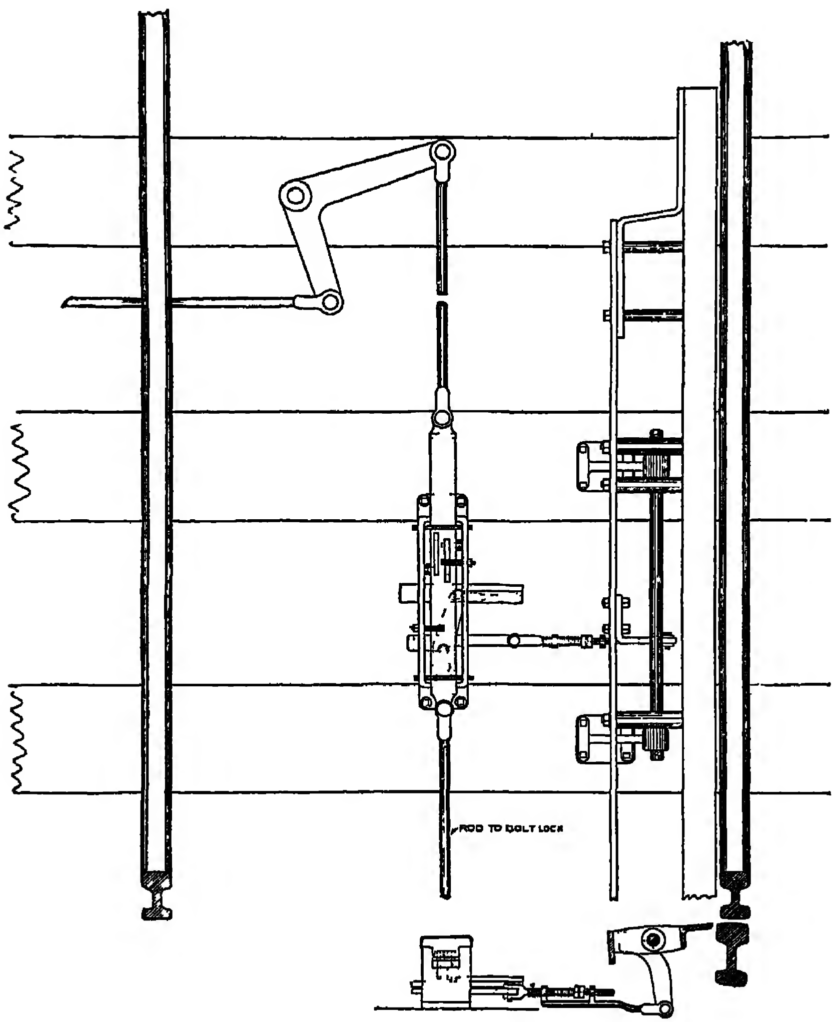


Fig 284—Hollands' Local Lock for Depression Bar

F P L bars, controlling a lock on the F P L lever, relieving the signalman of the weight of the bar usually employed, which is an important matter now that bars have to be made long enough to cover the wheel base of

70-ft coaches The same kind of bar, but operating a mechanical lock, known as a depression-bar lock, is also used on some lines, notably the Southern Railway, where Hollands' lock, shown in fig 284, is employed The lock acts on the F P plunger in such a way that the signalman can lock but cannot unlock the points when a vehicle is on the bar The apparatus is manufactured by Sykes Interlocking Signal Company These locks are sometimes called local locks They are very valuable in crowded yards, as the depression bars can easily be fixed to the tongues of points and are more convenient than ordinary mechanical lock bars fixed in a similar position Mechanical lock bars are also frequently broken during shunting movements, owing to a vehicle coming on the bar as it is being thrown, but with depression bars this cannot occur

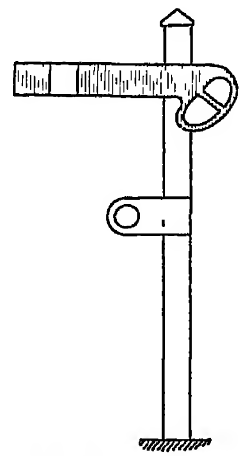


Fig 285 —Indicator Plate for Fireman's Plunger

Train-waiting Indicator —At busy signal cabins a train often stands at a signal without being observed for some time If track-circuiting is not in use a train-waiting indicator operated by a treadle is very useful The " train-waiting " indication is accompanied by the sounding of a buzzer and is reset when the signal is pulled off for the train to proceed

Train-waiting Plunger for Fireman —Instead of a treadle or track-circuit, a train-waiting indicator may be operated by a hand plunger fixed in a case on the signal post The fireman depresses the plunger when the train arrives, and this operates an indicator in the cabin and locks the relative block instrument where necessary An audible return indication is given at the signal post showing that the warning in the cabin has been given. If no return indication is received Rule 55 must be carried out Signals fitted with this arrangement are often distinguished by enamelled plates, as shown in fig 285

To enable enginemen to know whether the rails upon which they are standing when waiting at a signal are track-circuited, some railways attach to the signal post or mount separately on a post at the end of the track circuit to which it applies, an illuminated plate showing " train-waiting indicator in box ", or similar suitable wording, while others employ a white diamond-shaped plate attached to the signal post

An engineman is permitted, when standing at a signal so equipped, to ignore Rule 55 This rule states in effect that when an engine or train has been brought to a stand, the fireman or guard, whichever is the nearer, must go to the signal box at once and warn the signalman of the presence of the engine or train on the line

Detached-vehicle Indicator —Where vehicles are left in platform lines, after being detached, the indicator shown in fig 286 is sometimes employed The shunter operates a switch, when a vehicle is detached, locking the lever in the cabin and actuating an indicator, and if thought desirable an alarm bell These switches are also employed in conjunction

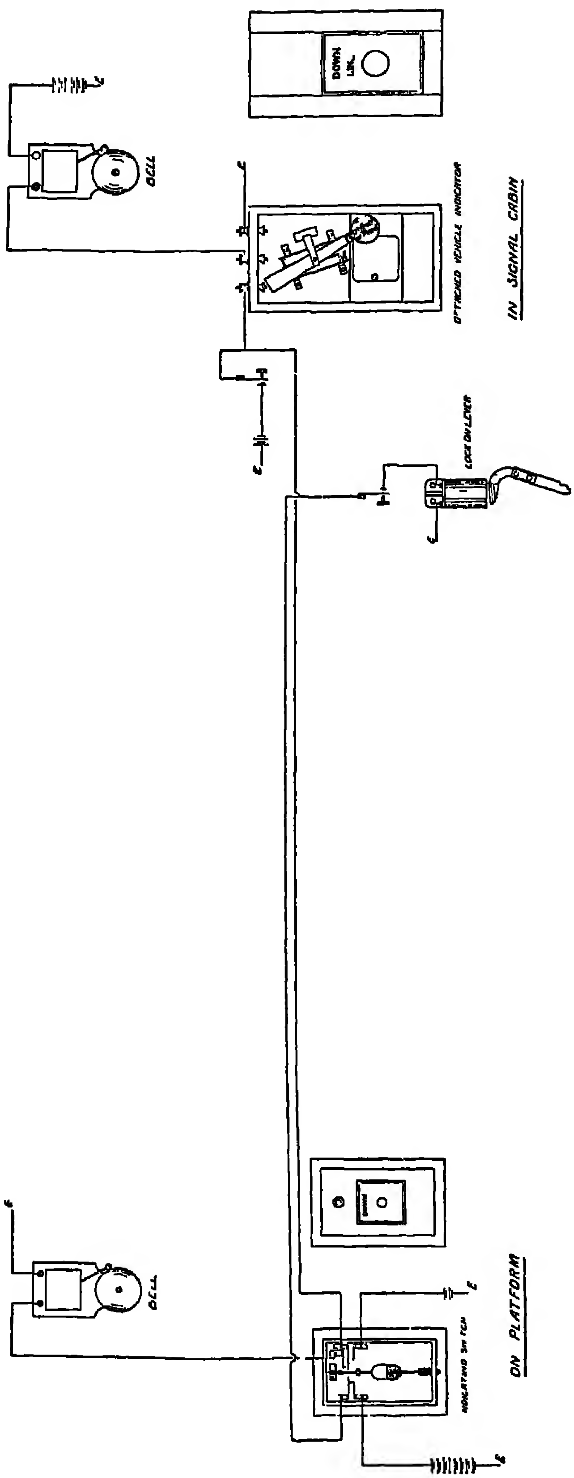


Fig 286 —Detached-vehicle Indicator

with track-circuiting to provide a safeguard against a possible failure to shunt the circuit

Supervising Inspector or Controller —At some stations a special cabin is provided giving a view over certain lines or even over all of them, an inspector being responsible for operating detached-vehicle indicators or equivalent apparatus whenever a line is obstructed, to remind the signalmen This method is general in Germany, where no movement is allowed to take place without the knowledge and consent of a superior official, called the traffic controller, who controls the signalmen by a special apparatus called the station block

Banner Signal —This is an electric signal, used generally as a repeater of some signal a short distance ahead which is obscured for some reason, although it is also used as a running signal in some places and to a considerable extent as a shunting signal It is due to Sykes Interlocking Signal Company It consists of a cast-iron case (fig 287) glazed at the back with an opal and at the front

with a clear glass The arm consists either of corrugated aluminium or more often of a light framework covered with bunting, and operated by a Z-armature fixed in the base A low-resistance winding is used to clear the signal, but a high-resistance winding to hold it at clear, reducing the current required to a very small figure, enabling the signal to be used at cabins which are switched out These signals are made in various sizes, and can stand up or hang down or even be fixed sideways They are illuminated from the rear and have practically the same appearance by night as by day, but the range of visibility at night is not very good and hence they are not used as running signals where high speeds may be expected They are very convenient as platform repeater signals and as shunting signals, eliminating all coloured lights from the latter, which is an advantage As repeaters of mechanical distant signals in tunnels, banner signals have often been used, being fixed just at the entrance and controlled by a contact on the signal concerned (fig 288) Banner signals may be repeated in the cabin by the usual repeaters

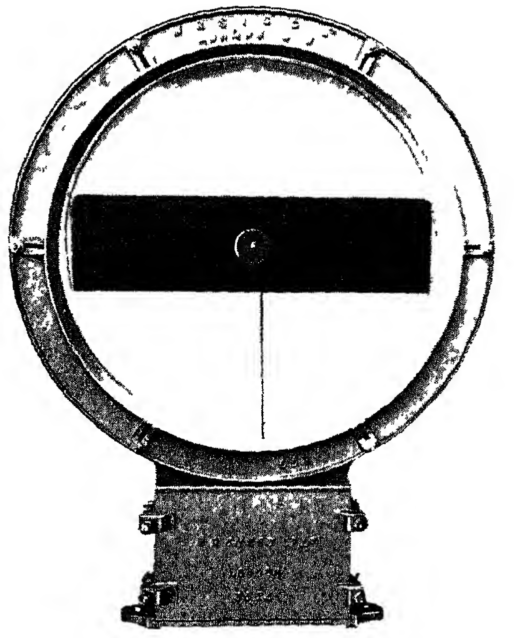


Fig 287 —Sykes' Banner Signal

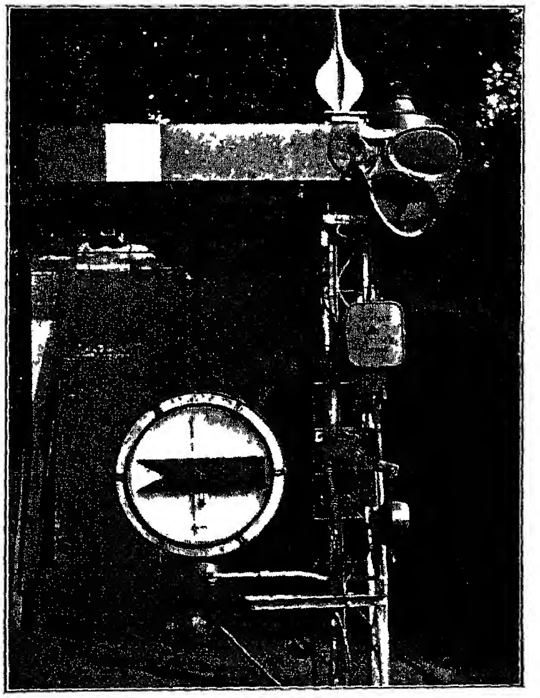


Fig 288 —Banner Signal repeating Mechanical Distant Signal in Tunnel

Closing and other Switches.—Fig 289 illustrates several forms of these which may be applied to various uses No description of them is necessary

Signal Selectors —Two conflicting signals, such as a home signal and a calling-on arm mounted on the same post, can be operated by one lever by means of an electric

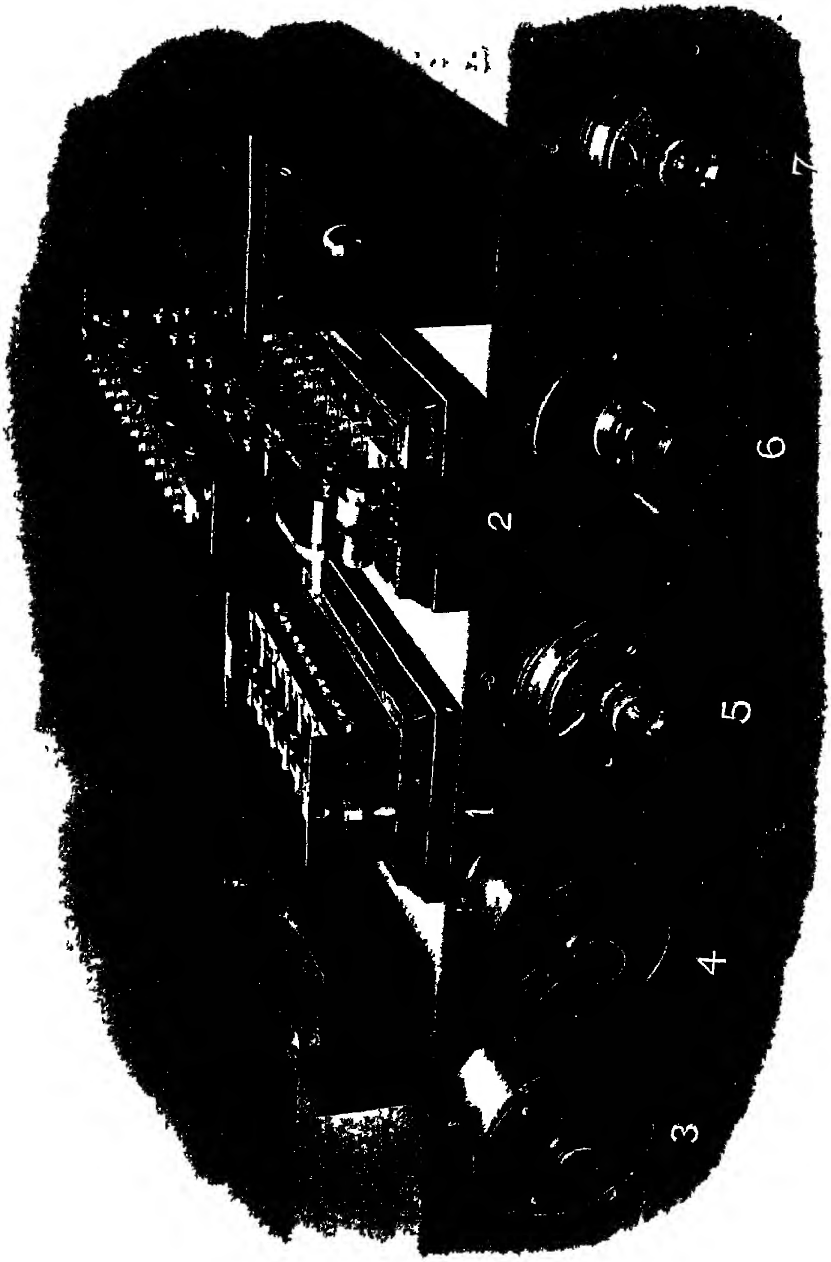


Fig 289—Closing and other Types of Switches

selector, illustrated in fig 290 This is often very useful in conjunction with track circuits, and economizes signal levers When the selector is energized the home signal can be cleared, but when it is de-energized the pulling of the lever clears the calling-on arm

Level-crossing Alarms—At what are known as occupation crossings an automatic alarm, set in action by the approach of trains, is a valuable safeguard, and although generally consisting of a large bell or gong it may also include a visual indicator Apparatus of this kind is very common in the United States, where level crossings are numerous and are seldom provided with gates or barriers of any kind These alarms may be operated by treadles or track circuits and used on double or single lines When treadles are used one is employed to start the alarm, placed at some distance

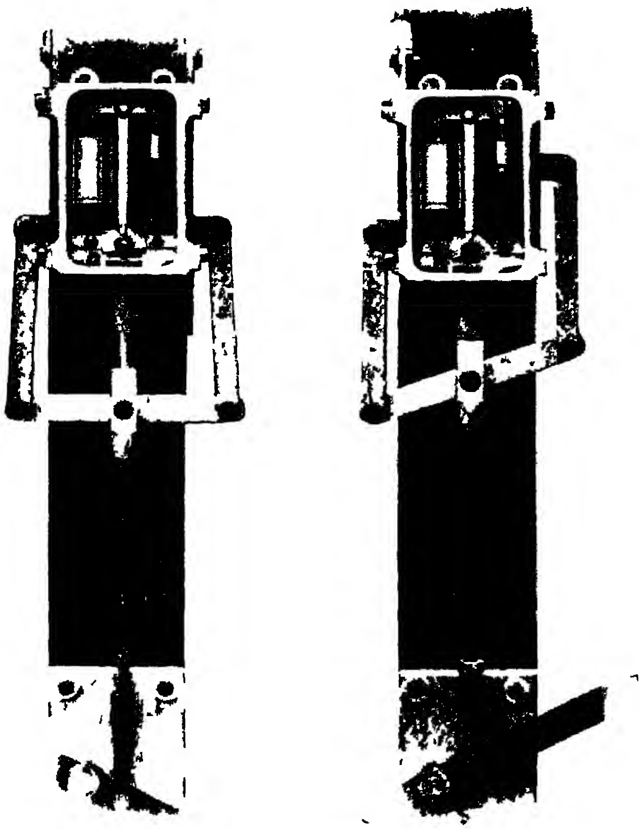


Fig 290—Electric Selectors

from the crossing, and another to stop it placed at or just past the crossing This is very simple on double lines, but on single lines the matter is complicated by the fact that a receding train must of course not sound the alarm This is usually accomplished by providing five treadles placed in the following order (stop, start,) stop, (start, stop) Those in brackets are quite close together, and thus a receding train in either direction passes over a silencing treadle last of all It is possible to dispense with these outer treadles and employ three only, as is done in the Siemens & Halske arrangement, but additional ingenious and rather delicate apparatus has

to be used to enable it to be done With track circuits, a circuit each side of the crossing is laid down, one on one line the other on the other on double track, either one occupied operating the alarm On a single track the two track relays are constructed as a so-called interlocking relay, and this operates in such a manner that a train going away from the crossing, although occupying a circuit, does not operate the alarm It is only the relay that is first released which can do so, as shown in fig 291

Gate-keepers' Indicators.—When crossings between block cabins are attended by gate-keepers it is customary to place what is called a hearing bell in the block circuit so that the gateman can hear all the codes which are exchanged and be prepared for approaching trains It is also useful

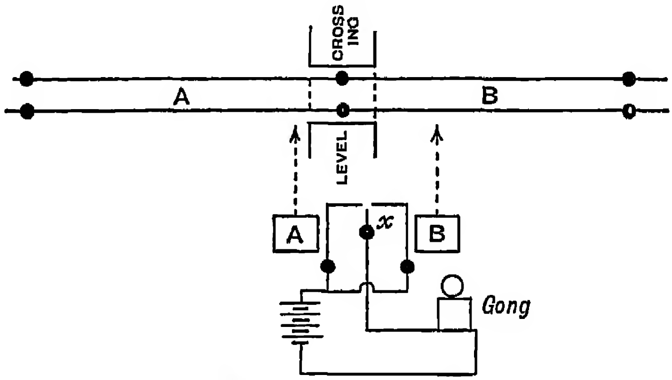


Fig 291 —Interlocking Relay for Crossing Alarm

Note Whichever relay armature is first released drops on to contact x and closes bell circuit The second armature falls on top of the first, and when the first one is raised, as the train passes the crossing, it lifts the second armature clear of the contact, thus silencing the bell
Bell rings only when a train is approaching the crossing

if the block indications are likewise repeated by visual indicators, which is easily done with three-wire block systems,[1] as a bell signal may be missed or misinterpreted

Conclusion —Electricity can be applied in so many different ways and there are so many appliances in use that an exhaustive description of them all is impossible Among those referred to even there are numerous patterns, made by various manufacturers to meet special requirements or the views of some particular engineer The use of electricity is extending, and in the next few years many mechanical appliances will have given way to devices operated by it A striking instance of this tendency is shown in the recent decision of the Norwegian State Railways to install no more mechanical signalling but to adopt electric power apparatus exclusively for future work

[1] It can be done with one-wire systems, but the apparatus is not so simple

APPENDIX

As mentioned in a number of places in the foregoing chapters, signalling has to comply with certain requirements of the Government For some years the revision of these had been under discussion between the Ministry of Transport and the railway companies, and in February, 1925, were issued the "Requirements for passenger lines and recommendations for goods lines of the Ministry of Transport in regard to railway construction and operation"

The requirements are divided into four sections

A Documents to be furnished
B Requirements and recommendations
C Modes of working single lines
D Appendices

Below are given extracts and quotations from the requirements so far as they relate to signalling The exact wording has been retained together with the section, paragraph, and clause numbers

A—DOCUMENTS TO BE SENT TO THE SECRETARY, MINISTRY OF TRANSPORT

NOTE—*The detailed information asked for under paragraph X, clause* 8, *should, whenever possible, without causing delay to the works, be forwarded in time to permit of examination by the Minister of Transport before works under this head are commenced*

X Detailed information under the following heads—

8th *Plans or Dimensioned Diagrams of the Signalling Arrangements* at all junctions, stations, block posts, &c

B—REQUIREMENTS AND RECOMMENDATIONS

NOTE—*These apply to construction or reconstruction and alterations or additions It will be seen that references are made in the text to the possibility of relaxation to meet individual cases It should also be noted that, in order to secure economy, with due regard to safety, when no references to relaxation are made, these Requirements may be modified at the discretion of the Minister of Transport, having regard to such special circumstances as may be submitted for consideration in each case Standardization of signalling and block working, &c, principles is also desirable With these ends in view, it will therefore be desirable to submit, whenever practicable, plans of works, for which approval is required, before they are commenced*

• *Attention is drawn to paragraph* 34 *and Appendix IV, which deal with the applicability of these Requirements to Light Railways and lines of local interest*

Block Telegraph

1 Apparatus to be installed for ensuring, by means of the Block Telegraph system, or by other approved method, e g automatic signalling, an adequate interval of space between following trains, and, in the case of junctions, between converging or crossing trains

In the case of single lines, or sections of single lines, worked by one engine or motor vehicle (or two or more such engines or vehicles coupled together) carrying a staff, no such apparatus will be required

On lines used purely for goods or mineral traffic, some other approved method of working may be substituted for Block Telegraph

On passenger roads, exemption from block working in special conditions may be granted when essential for traffic purposes

Signals

2 In the interests of economy, and to avoid confusion, the number of signals provided, and their height, should be limited to what is actually necessary for safety and traffic purposes

Up and down Distant signals for each block post, to be provided on all running lines which have two-position Stop signals One Distant signal in each direction, with the necessary control from each signal-box, is sufficient for a number of block posts closely grouped together, unless there are good reasons to the contrary

At diverging junctions, one Distant signal only should be provided, worked for the junction line over which the highest speed is permissible, unless in exceptional circumstances more are essential

Where special circumstances, e g permanent speed restriction, justify the adoption of an unworked signal, it should be secured in the warning position and not coupled up or duplicated for directing purposes

The interval between a Distant signal and the first Stop signal to which it applies must be such that a train in proximity to the former, and moving at the highest authorized speed, can be stopped before passing the latter

Stop signals to be provided for each up and down line at all block posts At diverging junctions, a separate running signal will be necessary for each direction of movement Where outer and inner Stop signals are provided on the approach to diverging junctions, it will not be necessary to give the full route indication at the former which is given at the latter

At stations with a number of diverging lines, one signal with indicating apparatus, for each approach line should, as a general rule, be provided instead of separate signals When, however, there are through fast lines, a separate arm should be provided for each On passenger lines, all connections within yard limits to be under protection of Distant and Stop signals

3 All signals, as a rule, to be immediately on the left of, or vertically over, the line to which they apply At diverging junctions, bracket signals are preferred to signals carried on separate posts, unless there are reasons to the contrary

In the case of shunting signals, where more than one are necessary, direction may be indicated by carrying them vertically one below the other, in which case the top signal will apply to the line on the extreme left, the second signal to the line next in order from the left, and so on

Distant signals to be distinguished from Stop signals during daylight by Yellow-coloured arms, with notches cut out of the ends They must be placed below, and be controlled by, Stop signals, if these are carried on the same post and applicable to the same direction A Distant signal placed under a Stop signal of the box in rear must, unless the circumstances are exceptional, be repeated under all Stop signals in advance of that signal which are worked from that box, with the necessary additional control by such signals

Signals for shunting movements should be readily distinguishable from running signals They should therefore be placed as close to the ground as the circumstances permit, and should be of the miniature arm or other approved type, with small lights

The facing side of the arms of all semaphores (including miniature), and the face of disc signals to be painted to accord with the colour of the light exhibited in the normal position

A special type of shunting signal for wrong line movement is not considered necessary In such cases where it is not possible to turn the movement in the right direction on to

a running line by reversing a cross-over or on to a siding by reversing the points, an indication, visible by night and day, of the limit of such movement will meet the case

Indications for "calling-on" movements to be given by a small semaphore arm carried under the relative Stop arm By night, a White light to be shown in the normal position and the light authorizing the "calling-on" movement to be Green "Calling-on" signals to be used only for the specific purpose of indicating to the driver, either that the line between the "calling-on" signal and the next Stop signal (or buffer stop, when there is no Stop signal in advance) is occupied, or that he is required to stop for instructions at the signal box ahead The "calling-on" signal should not therefore be capable of being worked at the same time as the relative Stop signal

For three-position signals, the arm indications, when used, to be horizontal for Danger, 45 degrees in the upper quadrant for Caution, and vertical for Clear The semaphore arms of both two-position and three-position Stop signals, when automatically worked without control from a signal-box, should be pointed at the ends

For two-position signals, the arm indication to be horizontal for Danger, and 45 degrees in the lower quadrant for Clear, except as may otherwise be approved

Signals to be so designed as to give a Danger indication in the event of any failure of the mechanism which operates them

Colour-light signals of an approved type for use by day, in lieu of semaphore arms, will be accepted

4 Front lights for all signals to be Red for Danger, Yellow for Caution (including the warning position of Distant signals), and Green for Clear These colours, in each case, to be within the approved standards White to be used for the back lights of signals

Back lights, visible only when signals are at Danger, and no larger than actually necessary, to be provided when the signalman cannot see the front light of any signal which he works, the arm of which is visible by day Back lights should be provided for all ground signals

For two-position shunting signals, the normal light indication may be either Red or Yellow The Red light to be used only when it is necessary to indicate that the signal is not to be passed without special permission, unless it is in the Clear position In other cases Yellow to be used In the case of shunt ahead signals carried under running arms, the lights used to be the same as those for "calling-on" signals

The arms of all Stop signals which cannot readily be seen by the signalman, and of all Distant signals, to be repeated in the signal-box from which they are worked It is desirable that the lights of all Stop signals and of all Distant signals upon important lines with high speed traffic, should be similarly repeated, unless either the front or back lights can readily be seen from an adjacent signal-box

To prevent confusion with signal lights, the use of coloured lamps for engine headlights or other purposes should be avoided Red to be used for tail-lamps

A Red light to be used by night to define the position of buffer stops at the termination of platform arrival lines

5 All worked signals, except where necessary at level crossings, should, as a rule, be dispensed with under the following conditions —

On single lines—

(*a*) At all stations and siding connections upon a line worked by one engine or motor vehicle (or two or more such engines or vehicles coupled together) carrying a staff, when all points are locked by such staff

(*b*) At any intermediate siding connection upon a line worked under the train staff and ticket system, or under the electric token system, where the points are locked by the train staff or electric token

In special conditions, signals may also be dispensed with at crossing loops upon a line worked under the train staff and ticket system, if the loop points are locked by the relevant staff

(*c*) At intermediate stations which are not token stations, upon a line worked under an electric token system, sidings, if any, being locked as in (*b*)

On double lines—

(*a*) At an intermediate siding connection, either where "lock and block" or other similar approved apparatus is in use, or where the points are mechanically or electrically controlled from one or both of the adjacent signal-boxes, and the relative running signals suitably interlocked

(*b*) At stations which are not block posts, where there are no connections

Points

6 Points to be so situated that movements over them shall be within view of the signal-box from which they are worked, unless an approved alternative for direct vision by the signalman, e g track circuited diagram, is provided

The limit of distance from levers working points to be 350 yards, unless the points are power worked and occupation of the lines is electrically indicated in the signal-box, in which case the distance may be indefinitely extended

All points to be fitted with not less than two stretchers Rodding is to be used throughout for the mechanical working of all points, and also for bolting them when required In certain conditions the use of unworked trailing points will be permitted

Facing points on passenger lines, and all points commonly used in the facing direction by passenger trains, to be fitted —

(*a*) With bolt-lock through a third stretcher, and with locking-bar, or some other approved device The operation of the bolt-lock must depend upon the correct movement of the locking-bar where it is used The length of locking-bars to exceed the greatest interval between any two adjacent axles likely to be used on the line

(*b*) With stock rail gauge tie

(*c*) With means for detecting the position of each switch, as well as the bolt-lock by the relative signals

It is desirable that—

(i) All trailing points used in the facing direction for shunting movements should be detected with the relative signals Single switch detection would be accepted in such instances

(ii) On goods lines, used exclusively for running movements, facing points should be equipped as on passenger lines

Signal-Boxes and Interlocking

7 The levers working points and signals to be brought close together in a signal-box, or on a properly constructed stage The signal-box to be sufficiently commodious to allow the signalman to have free access where necessary to windows It should be provided with a clock, and with up and down three-position block instruments for signalling trains on each line of rails The point levers and signal levers to be so placed in the box that the signalman, when working them, shall have a thoroughly good view of the railway, and the box itself to be so situated, elevated and constructed as to enable the signalman to get the best possible view of all the operations for which he is responsible Lights in the signal-box to be so arranged as not to be mistaken for fixed signals Telephone communication between signal-boxes is desirable

Adequate arrangements to be made where necessary for reminding the signalman of vehicles which are standing within his control In the case of passenger lines with high speed traffic, or where light engine, crossing, &c, movements are frequent, these arrangements should preferably be automatic when Stop signals are at a considerable distance from the box, or the signalman's view is likely to be obstructed

8 Point and signal levers to be so interlocked that the signalman shall be unable to clear a fixed signal for the movement of a train, until after he has set the points in the proper position for it to pass, and bolted them as necessary, that it shall not be possible for him to clear at one and the same time any two fixed signals, which may lead to a collision between two trains, and that, after having cleared the signals to allow a train to pass, he shall not be able to move any points connected with, or leading to, the line on which the train is moving until the signal is replaced Points also, where necessary, to be so interlocked as to avoid the risk of a collision

Levers operating Stop signals, which are next in advance of trailing points, operated from the same box, when worked, to lock such point levers in either position, unless this locking will unduly interfere with, and the interval between the relative signals and points is adequate for, traffic movements

Distant signal levers must be so interlocked that the signals cannot give a Clear indication when any of the relative Stop signals are at Danger

Electrical locking may be necessary in certain conditions between block instruments, or token instruments, and the levers operating points or signals

Interlocking between the up and down token instruments may also be necessary on a single line where there is a block post which is not a passing place

With track circuit in use for reminding a signalman of vehicles standing within his control, the occupation of the track should be shown by an indicator in the box, and should, when necessary, electrically lock the running signal, or signals, in rear leading on to the same line, or alternatively controls the block instrument

With automatic and controlled automatic signals and continuous track circuiting, the occupation by a vehicle of any section of track circuit should return to, and hold at, danger a sufficient number of signals in rear to provide an adequate interval between following trains The occupation of any track circuited section of line may also be required to lock electrically, as necessary, in one or both positions, points on or crossing over, that section

Sidings and Safety Points

9 Sidings to be so arranged that shunting operations upon them shall involve the least possible use of, or obstruction to, running lines The possible necessity for having in the future to extend passenger platforms should not be lost sight of in designing the layout of stations

Safety points to be provided upon goods and mineral lines and sidings, at their junctions with passenger lines, with the points normally set against the passenger lines and interlocked with the signals

Facing safety points, with or without an overrun or sand drag, may also be necessary —

(*a*) On single lines, at crossing places, where an adequate interval of space is not provided between the Stop signal controlling the approach to the loop and the fouling point of the loop lines at the other end, and

(*b*) On bay and loop platform lines, as a protection to traffic on the through lines

Junctions, &c

10 Where it is difficult for a signalman to estimate clearance, it may be necessary to provide bars, or other approved device, in order to define the fouling points of junctions, siding connections, crossings, &c

Gradients

16 It is desirable to avoid constructing a station on, or providing a siding in connection with, a line which is laid upon a gradient steeper than 1 in 260

In the case of steeper gradients, either at a station or siding connection, or within a section between two block posts where the level of one is appreciably lower than that of the other, danger may arise —

(*a*) In the case of engines being overpowered by their load,

(*b*) From vehicles running backwards, in the case of trains, which have become divided, and

(*c*) From vehicles running away after having been uncoupled on a running line

On double lines, one or both of the following arrangements may then become necessary —

(i) The provision of worked facing safety points, with or without a sand drag, when a special arrangement to utilize an existing facing siding connection is not practicable

(ii) The provision of a single or double self-acting throw-off switch a full train's length in rear of the first Stop signal of the higher block post on the ascending line, when a special arrangement to utilize an existing trailing connection at the lower block post is not practicable

On single lines, except where it is possible to work the traffic with an engine at the lower end of an unfitted train, one or more of the under-mentioned measures may be necessary —

(i) The provision of worked safety points or sand drag, facing the normal direction of descending traffic in a suitable position in the loop at one or both of the block posts, where a suitable arrangement to utilize an existing facing siding connection is not practicable

(ii) The provision of trailing safety points at the lower end of either an existing or specially constructed loop

(iii) The provision of an additional siding, in which the whole of a train can be placed clear of the main line before shunting operations are commenced

(iv) The provision of properly interlocked worked points, a sufficient distance from a siding connection, which can be set as a trap behind vehicles standing below that connection

Turntables

17 All turntables to be adequately lighted They should be kept at a safe distance from adjacent lines of rails, otherwise the turntable bolt must be interlocked in the signal lever frame

Permanent-Way

25 Fixed diamond crossings must not be flatter than 1 in 8 except in special circumstances Movable diamond crossings may be at any angle and are to be treated as worked facing points

Standard Dimensions —Clearances

26 —(1) *Structural Clearances —New Lines*

In the case of New Lines, after allowance has been made for curvature, super-elevation, and length of rolling stock, the standard static lateral clearance, measured between the point of maximum over-all body width of the broadest stock likely to be used on the line and any standing work, including standards carrying overhead electrical equipment (other than passenger or loading platforms, bridge girders, or disc or miniature signals, up to a height of 3 feet from rail level), over the whole vertical height between rail level and the top of the highest carriage doors, to be as follows —

(i) 2 feet 4 inches in respect of all structures Special consideration to be paid to the position of cables, &c , or attachments of any description in tunnels and under bridges

(ii) 2 feet in respect of all signal and lamp-posts, ladders, water columns, &c In cases of special difficulty, where signal posts, &c , are placed between tracks with only 9 feet clear interval (*vide* para 27), the minimum clearance of 18 inches from body-work is permissible

Level Crossings

28 —(1) At all level crossings of public roads, gates, where they are prescribed, must be constructed to close completely across the railway or across the road on each side of the crossing They must not, as a rule, be hung so as to admit of being opened outwards towards the road Stops to be provided to keep them in either position

When the normal position of gates is across the roadway, arrangements will be required to work them either from a signal-box, or by an attendant, for whom special accommodation may be necessary Where the normal position of gates is across the railway a special attendant will not be necessary if the gates can be opened when required and closed by the trainmen

At public road level crossings in or near populous places the gates to be either close-barred or covered with wire netting

Red discs or targets for daylight and red lamps, one on each side of the crossing, for night, to be fixed on gates, the discs or targets, and lamps, according to the position of the gates, to show towards the road, also towards the railway if there is no fixed Stop signal at the gates One such disc or target and lamp to be fixed on the gates on each side of the crossing

Fixed railway signals will not be required when, having regard to the traffic, gradients, &c , a sufficiently good view of the discs or lamps is obtainable by enginemen of approaching trains to enable them to stop short of the gates when they are across the railway When, however, the view obtainable by enginemen is insufficient for this purpose, and it is considered necessary to give additional protection beyond that furnished by the gate discs or lamps, a fixed signal of the Distant signal type to be provided The Distant signal may be either of the one-position unworkable type, when it is desired to give warning only of the proximity of the level crossing, or of the two-position worked type when information in

respect of the actual position of the gates at the level crossing is conveyed In the latter alternative the Distant signal must be interlocked with the gates

At important level crossings, or where conditions require them, Stop as well as Distant signals interlocked with the gates will be necessary

At all level crossings of public roads or footpaths a bridge or a subway for pedestrians may be required

Attendants at level crossings provided with gates should, as a rule, receive warning by bell or otherwise of the approach of trains from either direction

(2) At public road level crossings when gates are not prescribed and cattle guards may be used to prevent trespass upon the railway, speed reduction and whistle boards will be required at suitable distances on the railway on each side of the level crossing Warning boards will also be required on each public road approach It will be necessary to ensure that a good view of the railway line in each direction is obtainable from the road approaches to the level crossing by clearing or lowering obstructions to sight such as hedges, &c

(3) For field, private and occupation road level crossings, single gates should be used They should be hung so as to open away from the railway line

29 Sidings connected with the main lines near a public road level crossing to be so placed that shunting may be carried on with as little interference as possible with the level crossing, and, as a rule, the points of the sidings to be not less than 100 yards from the crossing

Light Railways

34 In respect of Light Railways, or lines of local interest, each case will be considered as regards the applicability of the foregoing Requirements, on merits, having in view the gauge, volume of traffic, axle-loads, and speed limits A general outline of some of the relevant variations and relaxations is given in Appendix IV

C—MODES OF WORKING SINGLE LINES

In the case of a single passenger line, an undertaking must be sent to the Ministry of Transport, through the inspecting officer, to the effect that one of the four following modes of working single lines will be adopted, namely —

I By train-staff and train-tickets in the mode described in the following rules, combined with the absolute block-telegraph system

Rules for working the single lines between A, B, C, &c

1 Either a train-staff or a train-ticket is to be carried with each engine or train to and fro, and for this purpose (one, two, or more) train-staffs and sets of train-tickets will be employed, e g —

	Colour of Staff and Ticket	Form of Staff and Ticket
One between A and B	Red	Square
,, ,, B and C	Blue	Round
&c &c	&c	&c

2 No engine or train is to be permitted to leave or pass either of the staff-stations, A, B, C, unless the staff for the portion of the line over which it is to travel is then at the station, and no engine-driver is on any account to leave or pass a staff-station without seeing such train-staff

3 If no second engine or train is intended to follow, the staff is to be given to the engine-driver

4 If other engines or trains are intended to follow before the staff can be returned, a train-ticket, stating "staff following" is to be given to the engine-driver of the first engine, and so on with any other except the last, the staff itself being sent with the last After the staff has been sent away, no other engine or train in the same direction is to leave the staff-station, under any circumstances whatever, until the return of the staff

5 The train-tickets are to be kept in a box fastened by an inside spring, and the key to open the box must be the train-staff, so that a ticket cannot be obtained without the train-staff The removal of the train-staff must lock the box

6 The train-staffs, the train-tickets, and the ticket-boxes are to be painted or printed

in different colours, e g red for the line between A and B, blue for that between B and C, &c , the inside springs and the keys on the staffs being so arranged that the red staff cannot open the blue box, or the blue staff the red box, and so forth

7 The ticket-boxes are to be kept in the signal-boxes or in the booking-offices at the staff stations

8 The sole person authorized to receive from an engine-driver, or exhibit or deliver to an engine-driver the staff or ticket is either the stationmaster, the inspector, the signalman, or the person in charge for the time at a staff station

9 In the event of an engine or train breaking down between two staff stations, the fireman or guard is to take the train-staff, if with the train, to the staff station in the direction whence assistance may be expected, so that the staff may be at that station on the arrival of an engine Should the engine or train that fails be in possession of a train-ticket instead of the staff, assistance can only come from the station at which the train-staff has been left The fireman will accompany any assisting engines to the place where the engine or train broke down

II By divided train-staff (without train-ticket) combined with the absolute block-telegraph system

In this case one-half of the staff will be marked " ticket " and the other " staff "

The rules for working a single line in this case will be similar in all respects to those above quoted, with the exception that the " ticket " portion of the staff is substituted when required for a train-ticket Each portion of the staff can be fitted with a key for controlling intermediate siding connections

(N B —For light railway working, the block-telephone in lieu of the block-telegraph system will be accepted with either of the above-mentioned modes of working)

III With only one engine or motor vehicle, or two or more such engines or vehicles coupled together upon the single line or any section thereof at one and the same time

Such engines or motor vehicles to carry the staff belonging to the line or section on which the train is travelling

(N B —No ticket to be allowed under this mode of working)

IV By an electric token system, under which only one of the tokens applying to any section can be in use at the same time

(N B —The approval of the Ministry of Transport to be obtained for the apparatus proposed to be used, and for the rules of working, which should be of a somewhat similar character to those detailed under mode of working, No 1)

V By any other method approved by the Minister of Transport

APPENDIX I

REQUIREMENTS IN REGARD TO THE PRECAUTIONS TO BE TAKEN AGAINST DANGER OF FIRE ON ELECTRICALLY OPERATED RAILWAYS

A —General to all Electrically Operated Railways

2 All cables to be insulated, as far as possible, with material which, in case of fire or fusing, will not give off dense smoke or fumes The method of fixing and protecting cables and other electrical equipment to be such as to minimise the possibility of fusing or arcing taking place

4 Platforms in underground stations not to be constructed of wood, and woodwork to be eliminated, as far as possible, from signal-boxes, lifts, offices, &c Soft or highly inflammable wood should not be used

15 Means to be provided for enabling drivers to put themselves into direct telephone communication with sub-stations, or adjacent railway stations, from any part of a tunnel on tube lines

APPENDIX IV

VARIATIONS FROM AND RELAXATIONS OF THE REQUIREMENTS IN THE CASE OF LIGHT RAILWAYS OR LINES OF LOCAL INTEREST

SECTION A is applicable as necessary

SECTION B —Para 1 *Block Telegraph* —An acceptable apparatus, where such is necessary at all, for providing an adequate interval of space between following trains will be some form of telephone instrument

Paras 2 to 5 *Signals* —Home and starting signals only for each direction at stations on single lines which are staff or electric token posts will be necessary Distant signals will not be necessary unless stop signals cannot be seen for a distance of a quarter of a mile Distant signals in such circumstances may be of the unworked type

Para 6 *Points* —An economical type of facing point lock, that is, one which enables the points, bolt lock, and locking bar (when used) to be worked by one lever, is recommended A locking bar will not be required when the lever working the facing points is alongside them Rodding for the mechanical operation of points may not be necessary

Paras 7 and 8 *Signal-boxes and Interlocking* —A ground frame which need not have overhead cover, is acceptable in lieu of a signal-box

Para 9 *Safety Points* —Worked scotches or derailers may be used instead of safety points, where protection is necessary

Paras 11 and 12 *Stations* —Platforms need not, unless traffic necessitates, be of greater width than six feet If the carriages are of the tramway type, or have adequate steps attached to enable passengers to descend and ascend from the ground, raised platforms are not necessary

Para 16 *Gradients* —This requirement is in general not applicable, but provision may be necessary to avert danger resulting from vehicles running back owing to the existence of steep gradients at stations or intermediate sidings

Para 17 *Turntables* —Not as a rule applicable

Paras 18 to 21 *Bridges and Viaducts* —Light standards of loading are permissible Reductions for impact effect on account of speed are given in the B S Specification No 153, Part III

Paras 22 and 23 *Permanent-way* —Not generally applicable The weight of rail in each case may be selected, having regard to speed, alignment, and general traffic conditions, from the range quoted in the following table —

Weight of Rail in Lbs per Yard	Maximum Axle Loading in Tons
30	4 to 6
35	5 to 7
40	6 to 8
45	7 to 9
50	8 to 10
55	9 to 11
60	11 to 13
65	13 to 15
70	15 to 17

Special cases will be considered on merits by the Minister of Transport

Para 24 *Check Rails* —Minimum radius may be taken as eight chains for the standard gauge

Para 28 *Level Crossings* —The arrangements are for consideration in each individual case

BIBLIOGRAPHY

The Block System of Signalling on American Railways (B B Adams, New York, 1901)
Block Signal Operation (W L Derr, New York, 1897)
The Application of Electricity to Railway Working (W E Langdon, London, 1897)
Railway Block Signalling (J Pigg, London, 1898)
Mechanical Railway Signalling (H R Wilson, London, 1901)
Power Railway Signalling (H R Wilson, London, 1908)
Railway Signalling in Theory and Practice (J B Latimer, Chicago, 1909)
First Principles of Railway Signalling (C B Byles, London, 1910)
Railway Signal Engineering (L P Lewis, London, 1912)
Automatic Block Signals and Signal Circuits (R Scott, New York, 1908)
Railway Signalling—Mechanical (F R Wilson, London, 1923)
Railway Signalling—Automatic (F R Wilson, London, 1922)
Modern Developments in Railway Signalling (A E Tattersall, London, 1921)
The Signal Dictionary (New York, 1911)
Electric Locking (J Anderson, Chicago, 1918)
Railway Signalling (E E King, New York, 1921)
The Maintenance of Way Encyclopædia (New York, 1922)
Étude sur les signaux des chemins de fer français (E Brame and L Aiguillon, Paris, 1883)
Le Block-system automatique sur les chemins de fer (R Delacourt and P E Prache, Paris, 1922)
La Nouvelle signalisation des chemins de fer de l'État belge (J Verdeyen and R Minet, Brussels, 1923)
Trattato moderno di materiale mobile ed ezercizio delle ferrovie (F Tajani, Rome, 1922–3)
Die Sicherungswerke im Eisenbahnbetriebe (Schubert-Roudolff, Berlin, 1921)
Die Sicherungsanlagen im Eisenbahnbetriebe (Cauer, Berlin, 1922)
Die selbsttatige signalanlage der Berliner Hoch- und Untergrundbahn (Kemmann, Berlin, 1921)

Proceedings of the Institution of Railway Signal Engineers (since 1913) (Reading, England)
Proceedings of the Railway Signal Association, later the Signal Section of the American Railway Association (since 1910) (New York, U S A)
The Invention of the Track Circuit, published by the latter Association at New York in 1922
" Railway Signalling " (formerly " Railway Signal Engineer " and " Signal Engineer "), published monthly at Chicago since 1909
" Zeitschrift fur das gesamte Eisenbahn-Sicherungswesen ", published fortnightly, afterwards monthly, at Berlin since 1906

INDEX

SOME ENGINEERING AND SCIENTIFIC WORKS

FROM BLACKIE AND SON'S LIST

Engineering

APPLIED HEAT Adapted from *Der Wärmeingenieur* by Dipl.-Ing. *Julius Oelschläger*, Chief Engineer, Wismar, Member of the Municipal Board of Works. Under the Editorship of *H. Moss*, D.Sc. (Lond.), A.R.C.S., D.I.C., Imperial College of Science and Technology. 30*s* net.

MODERN RAILWAY SIGNALLING By *W. G. Tweedie*, A.M.I.E.E., M.I.R.S.E., and *T. S. Lascelles*, M.I.R.S.E. 20*s* net.

STEAM CONDENSING PLANT. In Theory and Practice. By *James Sim*, B.Sc.Eng.(Lond.), Chief Designer, Condenser Department, Messrs. J. & J. Weir, Ltd., Cathcart, Glasgow. 18*s* 6*d* net.

THE ELEMENTS OF MACHINE DESIGN By *S. J. Berard*, Assistant Professor of Drawing and Machine Design, Brown University, and *E. O. Waters*, Assistant Professor of Machine Design, Sheffield Scientific School, Yale University. 10*s* net.

THE CHOICE OF SWITCHGEAR. For Main- and Sub-Stations. By *H. A. Coates*, M.I.E.E., A.Am.I.E.E. 20*s* net.

COST OF POWER PRODUCTION BY INTERNAL-COMBUSTION ENGINES By *G. A. Burls*, M.Inst.C.E. Fully illustrated. 5*s* net.

THE INTERNAL-COMBUSTION ENGINE. By *Harry R. Ricardo*, B.A., A.M.Inst.C.E., M.I.A.E. In two volumes.

Vol. I.—**General Thermodynamical Principles and Slow-speed Engines.** 30*s* net.
Vol. II.—**High-speed Engines and Recent Research Relating Thereto.** 30*s* net.

HYDRO-ELECTRIC ENGINEERING Edited by *A. H. Gibson*, D.Sc., M.Inst.C.E., M.I.Mech.E. In two volumes.

Vol. I.—**Civil and Mechanical Engineering.** 25*s* net.
Vol. II.—**Electrical Engineering.** 30*s* net.

SEWAGE TREATMENT AND DISPOSAL A Manual for Municipal and Sanitary Engineers and Managers of Sewage Disposal Works. By *G. M. Flood*, B.Sc.(Eng.), A.M.Inst.M.&C.E., F.I.S.E., M.R.San.I., Lecturer in Municipal and Sanitary Engineering at the Manchester College of Technology and the University of Manchester. 10*s* net.

PRINCIPLES OF SANITATION AND PLUMBING By *Richard H. Bew*, Registered Plumber, Member Royal Sanitary Institute, Head Teacher of Sanitary Engineering and Plumbers' Work, London County Council School of Building, Brixton. 7*s* 6*d* net.

Blackie's Applied Physics Series

OPTICAL MEASURING INSTRUMENTS **Their Construction, Theory, and Use** By *L C Martin*, F R A S , D Sc , A R C S , D I C , Lecturer in the Optical Engineering Department, Imperial College of Science and Technology, South Kensington 17*s* 6*d* net

COLOUR AND METHODS OF COLOUR REPRODUCTION By *L C Martin*, F R A S , D Sc , A R C S , D I C With chapters on **Colour Printing** and **Colour Photography** by *William Gamble*, F R P S , F O S Second impression 12*s* 6*d* net

PHOTOGRAPHY AS A SCIENTIFIC IMPLEMENT Second impression 30*s* net A Collective Work

Photographic Optics By Professor *A E Conrady*, A R C S
Astronomical Photography By *Charles Rundle Davidson*, F R A S
History of Photography By *Charles R Gibson*, F R S E
Photography in Printing By *William B Hislop*
Aeronautical Photography By Squadron Leader *F C V Laws*, O B E , F R P S , R A F
Photography in the Engineering and Metallurgical Industries By *John Henry G Monypenny*
Photography in Physics By *H Moss* D Sc (Lond), A R C S , D I C
The Technics of Kinematography By *Arthur S Newman*
Photomicrography By *George H Rodman*, Hon F R P S
The Elementary Optics of Photography **The Theory of Photographic Processes and Methods** By *S E Sheppard* D Sc (Lond), F C S
Colour Photography By *W L F Wastell*, F R P S
The Camera as Witness and Detective By *Wilfred Mark Webb*, F L S , F R M S
Photography in Surveying By Colonel *H S L Winterbotham*, C M G , D S O

METEOROLOGY **An Introductory Treatise** By *A E M Geddes*, O B E , M A , D Sc , Lecturer in Natural Philosophy in the University of Aberdeen 21*s* net

MECHANICAL PROPERTIES OF FLUIDS An Account of Recent Engineering Research 20*s* net A Collective Work

Introduction By Engineer Vice-Admiral Sir *George Goodwin*, K C B , LL D
Liquids and Gases By *Allan Ferguson*, M A , D Sc (Lond)
Mathematical Theory of Fluid Motion By Professor *Horace Lamb*, LL D , Sc D , F R S
Viscosity and Lubrication By *A G M Michell*, M C E
Stream-line and Turbulent Flow By Professor *A H Gibson*, D Sc
Phenomena due to the Elasticity of a Fluid By Professor *A H Gibson*, D Sc
Hydrodynamical Resistance and Dynamical Similarity By Professor *A H Gibson*, D Sc
The Determination of Stresses by means of Soap Films By *G I Taylor*, M A , F R S
Wind Structure By *A E M Geddes*, O B E , M A , D Sc
Submarine Signalling and Transmission of Sound through Water By *C V Drysdale*, D Sc (Lond)
The Reaction of the Air to Artillery Projectiles By *F R W Hunt*, M A

ELECTRICITY and its Practical Applications A Text-book of Electrical Engineering By *Magnus Maclean*, D Sc , LL D , F R S E , M I E E 10*s* 6*d* net.

FUEL AND REFRACTORY MATERIALS By *A Humboldt Sexton*, F I C , F C S , Past President of the West of Scotland Iron and Steel Institute, &c New Edition, completely revised and enlarged by *W B Davidson*, D Sc , Ph D , F I C 12*s* 6*d* net

Theoretical Physics

SPACE AND TIME By *Émile Borel*, Honorary Director of L'École Normale Supérieure, Professor of Mathematical Physics in the Faculty of Sciences of Paris, Member of the Institute 7*s* 6*d* net

A semi-popular account of the Theory of Relativity by one of the most distinguished of living French mathematicians

Manuals of Pure and Applied Chemistry

General Editor *R M Caven*, D Sc (Lond), F I C

THE STRUCTURE OF MATTER By *J A Cranston*, D Sc , A I C , Lecturer in Physical Chemistry, Royal Technical College, Glasgow Second impression 12*s* 6*d* net

CHEMICAL SYNTHESIS Studies in the Investigation of Natural Organic Products By *Harry Hepworth*, D Sc (Lond), F I C , a member of the Research Staff of Nobel Industries, Ltd 20*s* net

COMPLEX SALTS By *William Thomas*, B A (Cantab), M Sc (Wales), Ph D (Aberdeen), A I C , Lecturer in Chemistry, University of Aberdeen 10*s* net

---

Blackie's Chemistry Textbooks

A TEXTBOOK OF ORGANIC CHEMISTRY By *A Bernthsen*, Ph D Edited by *J J Sudborough*, Ph D , D Sc , F I C , formerly Professor of Organic Chemistry in the Indian Institute of Science, Bangalore 12*s* 6*d* net

PRACTICAL ORGANIC CHEMISTRY By *J J Sudborough*, Ph D , D Sc , F I C , and *T Campbell James*, D Sc , F I C , Professor of Chemistry, University College of Wales, Aberystwyth A companion book to *Sudborough's* edition of *Bernthsen's* " Organic Chemistry " 8*s* net

SYSTEMATIC INORGANIC CHEMISTRY From the Standpoint of the Periodic Law By *R M Caven*, D Sc (Lond), F I C , Professor of Inorganic and Analytical Chemistry in the Royal Technical College, Glasgow, and *G D Lander*, D Sc (St And and Lond), F I C 9*s* net

SYSTEMATIC QUALITATIVE ANALYSIS For Students of Inorganic Chemistry By *R M Caven*, D Sc (Lond), F I C 5*s* net

QUANTITATIVE CHEMICAL ANALYSIS and Inorganic Preparations. By *R M Caven*, D Sc (Lond), F I C 8*s* net

Also issued in Two Parts

PART I **Preparation of Inorganic Salts, and Simple Exercises in Gravimetric and Volumetric Analysis** 3*s* 6*d* net

PART II **Volumetric Analysis Gravimetric Separations Analysis of Minerals and Alloys Preparation of Inorganic Compounds** 5*s* net

THE FOUNDATIONS OF CHEMICAL THEORY The Elements of Physical and General Chemistry By *R M Caven*, D Sc (Lond), F I C Second Edition, revised and enlarged 12*s* 6*d* net

ATOMS AND MOLECULES Being Part I and Chapter XII of "The Foundations of Chemical Theory" By *R M Caven*, D Sc (Lond), F I C 7*s* net

AN INTRODUCTION TO ANALYTICAL CHEMISTRY By *G G Henderson*, D Sc , LL D , F R S , F I C , Professor of Chemistry in the University of Glasgow, and *M A Parker*, B Sc , F I C , F C I C , Professor of Chemistry in the University of Manitoba, Winnipeg 5*s* net

PRACTICAL ORGANIC CHEMISTRY For Students of Pharmacy and Medicine By *I Vance Hopper*, Ph D , A R C S I , F I C , and *William M Cumming*, D Sc , F I C , Lecturers on Organic Chemistry, The Royal Technical College, Glasgow 4*s* net